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Eocene Minettes and their Mica-Clinopyroxenite Inclusions in the Milk River area, southern Alberta: Nature and Origin

BY ARNDT L. BUHLMANN ©

Department of Earth and Atmospheric Sciences
Edmonton, Alberta

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Eocene Minettes and their Mica-Clinopyroxenite Inclusions in the Milk River area, southern Alberta: Nature and Origin** submitted by Arndt Leonhard Buhlmann in partial fulfillment of the requirements for the degree of Master of Science.

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Dedicated To: E.B.

Abstract

Several mica-clinopyroxenite inclusions and host rocks have been collected from exposures of mafic alkalic igneous rocks in southern Alberta that are northern outliers of the Eocene-age Sweetgrass Hills igneous complex (50-54 Ma) of the Montana high-potassium province. The exposures, dominated by minettes, occur as dykes, sills and plugs as well as extrusive rocks. The minettes contain the phenocrysts assemblage phlogopite + diopside ± olivine pseudomorphs. The inclusions are generally coarse grained and contain phlogopite + diopside ± apatite. The mineral compositions are similar in both the nodules and associated host rocks. Complex zoning and textures, of phlogopite and clinopyroxene, in the minettes and nodules are interpreted as indicating that mixing between minette magmas of varying degrees of evolution has occurred.

Both minettes and mica-clinopyroxenites are K- and Mg-rich and are enriched in LIL elements, Ni, Cr, and V. The inclusions differ from the associated minette dykes in having lower Al_2O_3 and Na_2O but higher MgO and CaO. In the minettes and inclusions $(^{87}Sr/^{86}Sr)_i$ ranges from 0.706 to 0.707, ε_{Nd} varies from -12 to -19 and Pb isotopic compositions are within the range $^{206}Pb/^{204}Pb$ of 16.958 to 17.687, $^{207}Pb/^{204}Pb$ of 15.285 to 15.499 and $^{208}Pb/^{204}Pb$ of 36.958 to 37.791. A Rb-Sr mineral isochron for an inclusion yields an age of 51.7 ± 1.8 Ma. Another nodule and an associated dyke yield phlogopite model ages of 48 ± 1 and 50 ± 1 Ma respectively.

Isotopic and trace element data are interpreted to show that the minettes contain multiple source components. The parent magmas are believed to have been generated at pressures greater than 17 kb from a mantle source containing olivine + clinopyroxene + phlogopite and subsequently evolved by fractional crystallization of olivine + clinopyroxene + phlogopite. The inclusions are interpreted to originate as magmatic cumulates crystallized from the minette dyke magmas at depth.

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I would like to thank Dr. Robert Luth, my supervisor, for his patience, insight, encouragement and the funding he provided me through NSERC and LITHOPROBE. It is this dedication that makes Bob an exceptional instructor. I thank Professor R. A. Burwash who originally encouraged me to take a look at Coulee 29 in the Milk River area, donated samples to the project, shared field observations and maps, and continued his enthusiasm during the entire project. His son in-law, Doug Nelson, is graciously thanked for providing access to the area.

This work benefited greatly from the work I was able to do in the isotope labs at the Department of Earth and Atmospheric Sciences, University of Alberta. I am indebted to Dr. Patricia Cavell for the number of hours she spent teaching me the ways of isotopic analyses and for allowing me to use her maps (Figures 2.1 and 2.2). Dr. Robert Creaser is thanked for inviting me to play with the big boys in the ultra-clean lab. His mastery of chemistry and mass spectrometry has provided me with the fundamental knowledge necessary for doing isotopic analyses.

Appreciation is expressed to my fellow graduate students for support through the years, especially, Steve Grant and Taro Yamashita who have listened to me talk at length about weird and strange rocks without falling asleep. Thanks also to Paul Wagner for help with the microprobe determinations. His boundless energy and sharp wit also kept me entertained during those long lasting probe sessions. I would also like to thank Don Resultay for making a mean thin section and providing me with worthwhile distractions like mountain biking. Appreciation is also expressed to my external examiner Dr. Arthur Mar.

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Chapter 1

Introduction

Undersaturated and related alkaline rocks are volumetrically insignificant igneous rocks, but they make up for this deficiency with a bewildering plethora of unrelated, uninformative and often unpronounceable names. The huge range in exotic names is accompanied by equally extreme variations in mineralogy, mode, major, trace element and isotopic compositions. Definitive classification, to date, is impossible as there is no agreement among petrologists with regard to the type of parameters to be employed in classification (Mitchell, 1996).

Recently it has been recognized that alkaline rocks have an importance out of all proportion to their absolute abundance among igneous rocks; they offer views into the mantle and clues to mantle processes, they are indicators to economic potential (diamonds and gold), they represent parental magmas to a wide range of other igneous rock types, and they represent sources to wide variations of exotic minerals and geochemical compositions (Rock, 1991). The term *lamprophyre* (Greek *lampros, porphyros,* glistening porphyry or purple rock) was coined by von Gumbel (1874) when describing the "mica traps" of the Fichtelgebirge (Germany), which contain large lustrous biotite phenocrysts. 'Glistening porphyry' or *lamprophyre* , therefore, is essentially a field term that describes the field appearance rather accurately.

The term *minette* was originally an old miners term for oolitic ironstones (Le Maitre *et al.*, 1989). Later, the term was used for a biotite, K-feldspar, -rich "shoshonitic" or "calc-alkaline" lamprophyre (Rock 1977, 1984, 1987, 1991).

The intrusive mafic alkalic igneous rocks in southern Alberta, which are northern outliers of the Eocene-age Sweetgrass Hills igneous complex, are dominated by the rock type characterized as minette by Williams and Dyer (1930) and by Russell and Landes (1940). We have retained the term minette for olivine-diopside-phlogopite-phyric rocks, which is consistent with its usage on analogous rocks described in the literature on the Highwood Mountains, Montana by O'Brien *et al.* (1988).

The existence of mica-clinopyroxenite inclusions within some of the minette exposures suggests the possibility that they have a cognate, cogenetic origin. This suite of mica-clinopyroxenites is inadequately characterized and it is important to determine their origins. If they are cognate, study of their relationship to the host minette might provide evidence regarding the crystallization sequence of minette at high pressure. This data may provide direct evidence of the importance of crystal fractionation processes in forming the spectrum of Milk River minettes and perhaps the related Sweetgrass Hills igneous complex rock types.

The primary objective of this study is to constrain the relationship between the mica-clinopyroxenites and the associated minette dikes as well as to describe the petrogenesis of the Milk River minettes using field information, petrography and modern analytical techniques to complement previous studies. The problems were approached on several levels of study. The first involves the petrographic descriptions of hand samples and thin sections of samples as well as the employment of electron microbeam methods. Major and selected trace element data were obtained for the minettes and mica-clinopyroxenites from the Milk River area to test the plausibility of relating them by fractional crystallization. Isotopic and trace element data were used to obtain information on the source region of the Milk River magmatism and to compare these rocks with other minettes from the Highwood Mountains and Bearpaw Mountains, central Montana.

The dissertation is organized into six chapters and an appendix. The Appendix is organized into separate sections represented by petrographic descriptions of selected samples, the electron microprobe data, major and trace element data, and radiogenic isotopic compositional data.

Chapter 2

Background Information, Rock Types and Mineral Chemistry

INTRODUCTION

Sampling and field work for this study were conducted on short field trips during the summers of 1992-1994. Additional samples collected on earlier occasions were loaned by the Provincial Museum of Alberta and Professor R. Burwash, from the University of Alberta. Included in this chapter is a brief account of the field relations at the study locality. This chapter also includes a summary of the petrography and mineral chemistry of rocks from the Coulee 29 minette vent complex, as well as other potassium-rich magmatic rocks in the Milk River area of southern Alberta. Petrographic descriptions and mineral chemistry data are listed in the Appendix A and B, respectively.

PREVIOUS GEOLOGICAL STUDIES

The first geological notes published about the mafic alkalic rocks in the Milk River area of southern Alberta and northern Montana were those of G.M. Dawson in 1884 and Weed and Pirsson, 1895; Kemp and Billingsley, 1921. Dawson (1884) described the dikes, sills and plugs as "mica-traps" and considered them to be related to the Sweetgrass Hills igneous complex to the south. The first mapping took place in the 1920s by Williams and Dyer (1930) and in the 1930s by Russell and Landes (1940) who proceeded to discover additional outcrops in the Milk River area. All exposures with the exception of a "porphyritic andesite" outcrop were described as minette. In 1972, Donald A. Taylor, from the Provincial Museum of Alberta, described most of the exposures as minette in his field notes. In the most recent study, Kjarsgaard (1994) used whole-rock major and trace element chemistry, mineralogy, and mineral chemistry to demonstrate that the mafic alkalic rocks are minettes and that they are similar to other minettes from the Montana alkaline province.

REGIONAL SETTING AND AGE RELATIONS

The study locality is one of several mafic alkalic exposures that are northern outliers of the Eocene-age Sweetgrass Hills igneous complex of Montana and southern Alberta. The Sweetgrass Hills igneous complex represents a dissected Eocene intrusive complex composed of syenites and highly potassic, mafic to felsic igneous rocks (Truscott, 1977; Marvin *et al.*, 1980) which represent the northernmost exposed extension of the 69-27 Ma Montana alkaline province (Fig. 2.1). The exposures in southern Alberta are characterized by a suite of minette dikes, plugs and sills as well as extrusive rocks, similar to minettes in the Highwood and Bearpaw Mountains. The Highwood Mountains, Bearpaw Mountains and Eagle Buttes form a northeast trending belt located approximately 200 km southeast of the Sweetgrass Hills and all were emplaced between 54 and 50 Ma (Hearn, 1976; Marvin *et al.*, 1980).

ROCK TYPES AND PETROGRAPHY

Field and petrographic descriptions by Kjarsgaard (1994) supplemented by petrography on ~ 100 samples from the ca. 200 samples collected during the course of the present study are briefly summarized in this section. Minettes comprise six out of seven of the igneous exposures in the Milk River area, and the other is described by Kjarsgaard (1994) as "an irregular mass of gray diorite porphyry". Fig. 2.2 is a generalized geologic map showing the outcrop locations.

Minette

The minette exposures occur either as dikes, sills or plugs and intrude sedimentary rocks of either the Milk River Formation, Foremost Formation, Pakowki Formation, or the Oldman Formation. All minette samples from the six outcrops may be distinguished on the basis of texture and mineralogy. The black *olivine minettes* usually have a seriate porphyritic texture and contain olivine pseudomorphs, phlogopite and diopside in a matrix of salite + sanidine + mica (Phl - Bt) + oxide + apatite ± carbonate ± analcime (Fig. 2.3). The second subtype, brown *minette* (or intermediate minette) usually have a hiatal

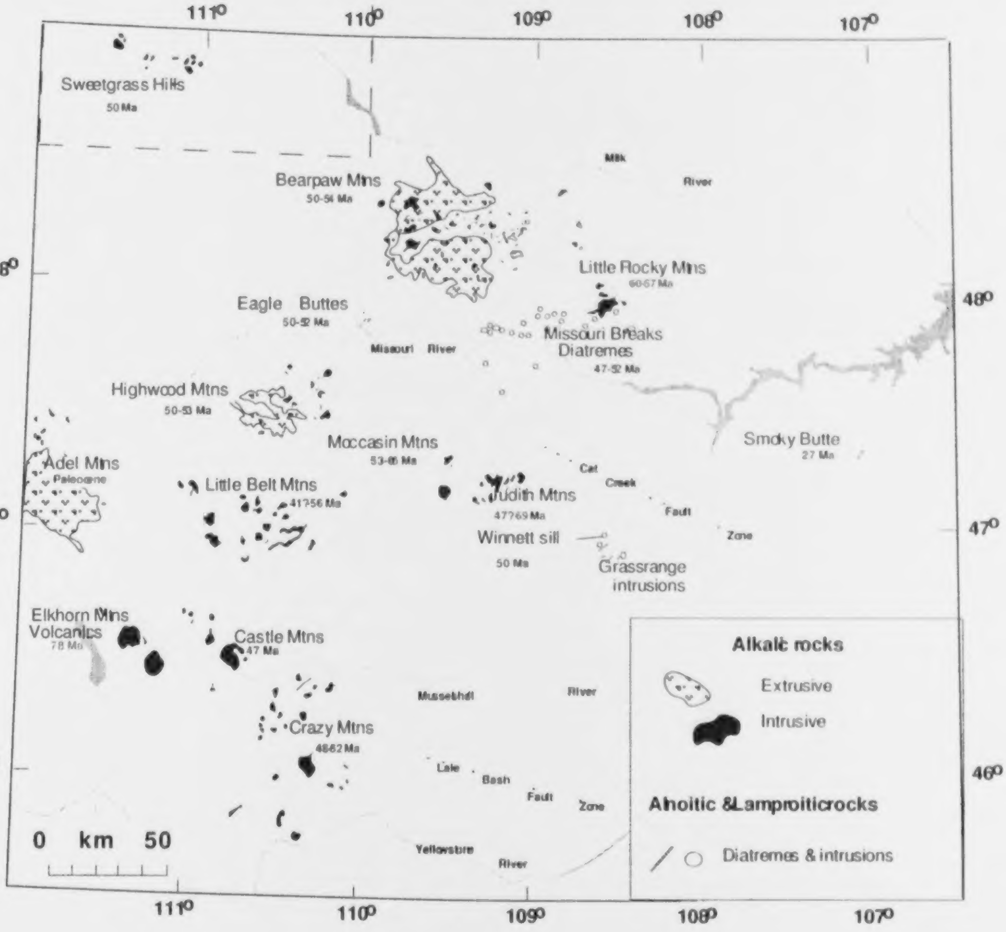

111°
110°
109°
108°
107°
48°
47°
46°
Sweetgrass Hills
50 Ma
Bearpaw Mtns
50-54 Ma
Milk
River
Little Rocky Mtns
60-67 Ma
Eagle Buttes
50-52 Ma
Missouri River
Missouri Breaks Diatremes
47-52 Ma
Highwood Mtns
50-53 Ma
Smoky Butte
27 Ma
Moccasin Mtns
53-65 Ma
Adel Mtns
Paleocene
Little Belt Mtns
41?56 Ma
Cat Creek Fault Zone
Judith Mtns
47?69 Ma
Winnett sill
50 Ma
Grassrange intrusions
Elkhorn Mtns Volcanics
78 Ma
Castle Mtns
47 Ma
Musselshell River
Crazy Mtns
48-62 Ma
Lake Basin Fault Zone
Yellowstone River
0 km 50
Alkalic rocks
Extrusive
Intrusive
Alnoitic & Lamproitic rocks
Diatremes & intrusions

FIGURE 2.1 Geological map of the Central Montana Alkalic Province. The Eocene Sweetgrass Hills represent the northernmost extension of the Montana Alkalic Province and consist of diorites to syenites and minettes. The Eocene Highwood Mountains, Eagle Buttes and Bearpaw Mountains trend consists of latites, mafic phonolites-shonkinites and minettes, the Sweetgrass Hills also belong to this same group. Modified by Cavell (unpublished, 1994) from Hearn (1989).

porphyritic texture with phlogopite and diopside phenocrysts in a fine grained groundmass of sanidine + salite + mica (Phl - Bt) + oxides (Fig. 2.4). The last subtype, termed *felsic minette*, has a K- feldspar and mica (Bt) rich matrix containing far fewer mafic phenocrysts.

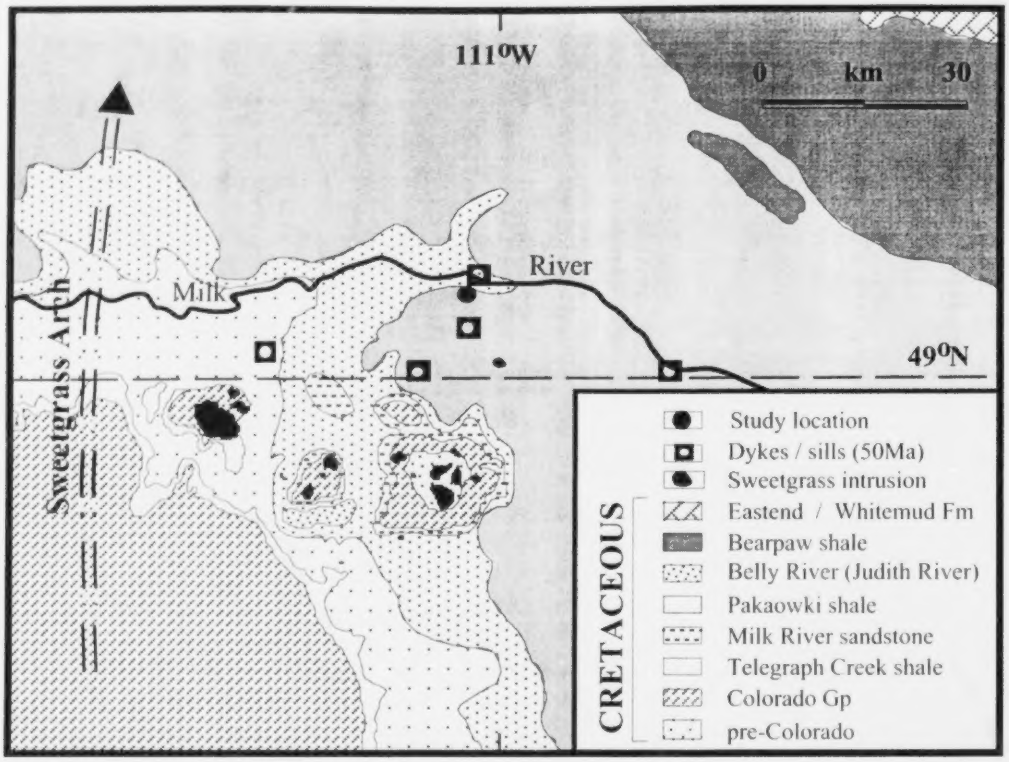

111°W
0 km 30
River
Milk
Sweetgrass Arch
49°N
Study location
Dykes / sills (50Ma)
Sweetgrass intrusion
CRETACEOUS
Eastend / Whitemud Fm
Bearpaw shale
Belly River (Judith River)
Pakaowki shale
Milk River sandstone
Telegraph Creek shale
Colorado Gp
pre-Colorado

FIGURE 2.2 Generalized geological map of the Sweetgrass Hills showing the locations of the minette dikes, sills, plugs, and the study location in southern Alberta, as well as the dioritic to syenitic stocks in northern Montana. From Cavell (unpublished, 1994).

The study exposure (Fig. 2.5), Coulee 29, is a minette vent complex consisting of several distinct magmatic packages, some containing a variety of xenoliths. The magmatic packages consist of a tan vent breccia, brown minette proximal vent volcanic rocks and brown *minette* and black *olivine minette* crosscutting dikes (Kjarsgaard, 1994). Xenoliths include locally derived sedimentary clasts, Precambrian tonalite gneisses, lower crustal mafic granulites and mica-clinopyroxenites.

Mica-clinopyroxenites

Mica-clinopyroxenite nodules are common in the minette dikes and breccia units at Coulee 29. The minerals in the nodules have similar compositions to those forming

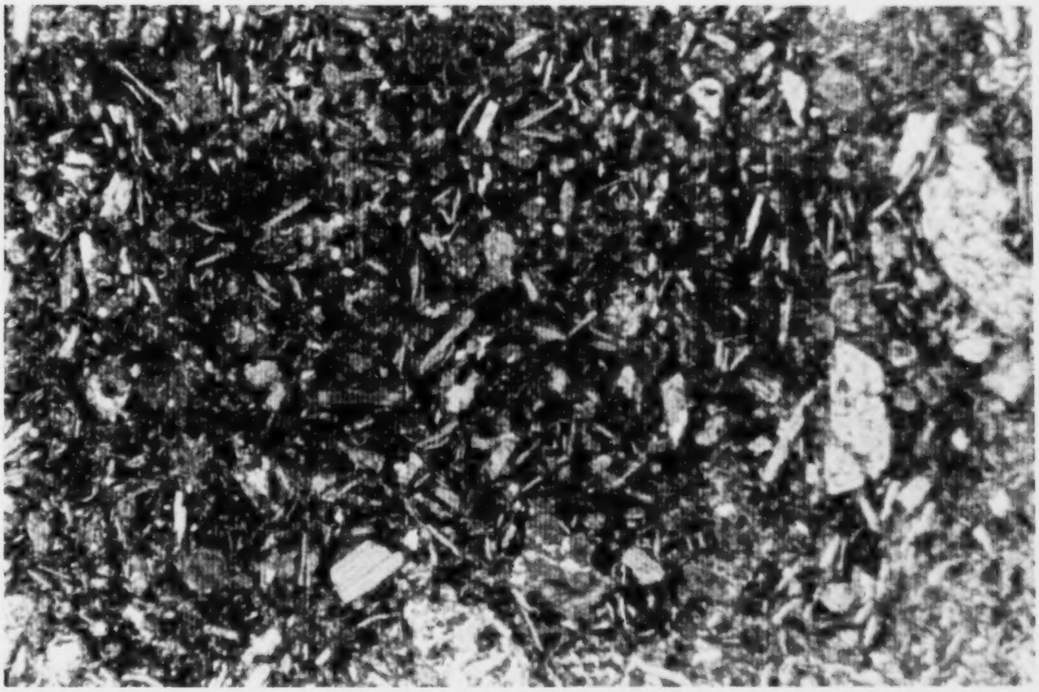


FIGURE 2.3 Photomicrograph of black *olivine minette* from Coulee 29. This rock has a seriate porphyritic texture containing abundant phenocrysts of phlogopite, diopside and altered olivine. The groundmass consists of salite, sanidine, mica, oxide and apatite microlites. Plane-polarized light; view is 7x10mm.

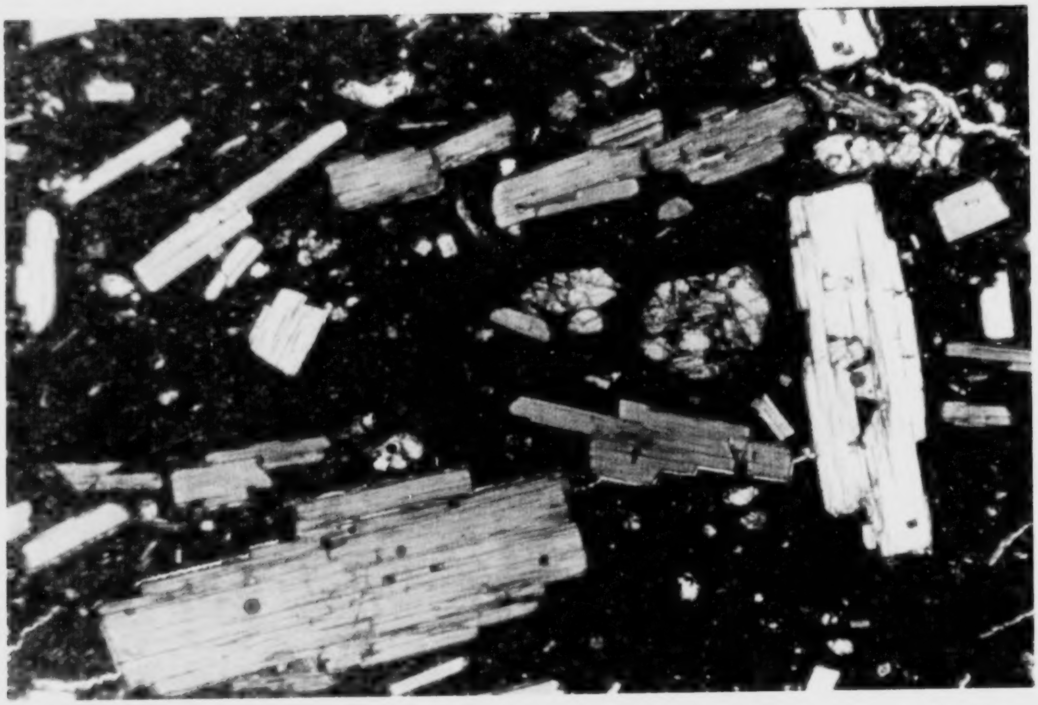


FIGURE 2.4 Photomicrograph of brown *minette* from Coulee 29. This rock shows a hiatal porphyritic texture with phlogopite and diopside phenocrysts in a matrix consisting of sanidine, salite, mica and oxides. Plane-polarized light; view is 7x10mm.

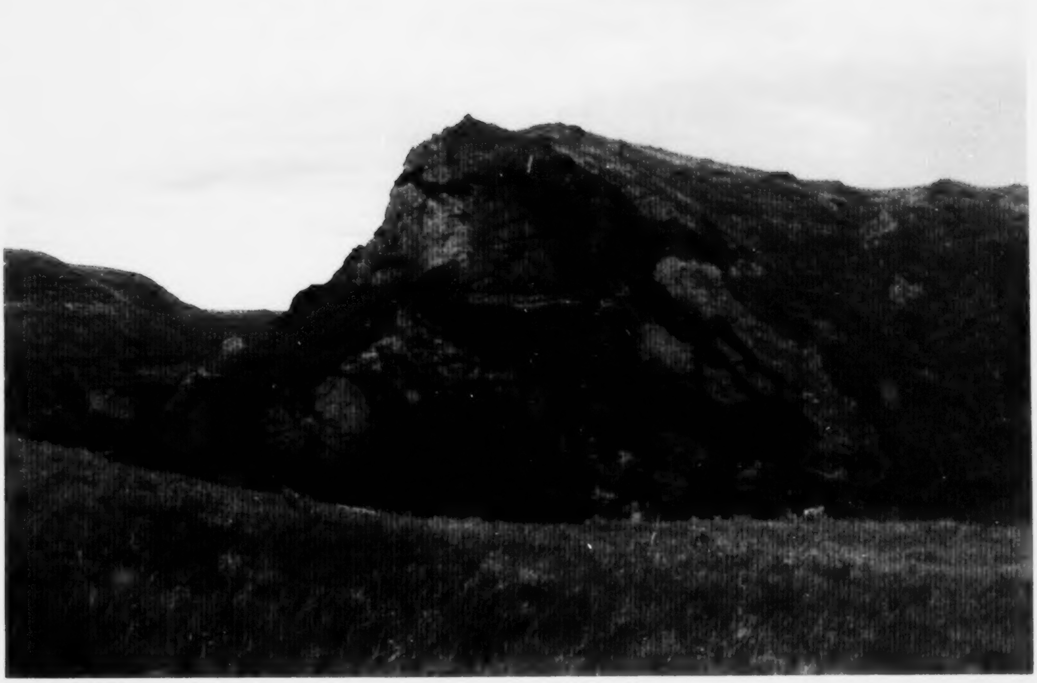


FIGURE 2.5 North looking view of the primary study locality, Coulee 29. The 29 exposure is an irregularly shaped minette vent complex consisting of multiple and distinct magmatic packages. Some of the units contain abundant locally derived sedimentary clasts, crustal xenoliths as well as cognate magmatic nodules.

phenocrysts in the associated minette samples. The varieties described for the purpose of this study can be broken into two groups.

1. The typical mineralogy of the nodule is (Fig. 2.6): clinopyroxene (Di - Sal)[1] + mica (Phl - Bt) ± apatite ± carbonate (dolomite or calcite) ± minor oxide (titanomagnetite). Grain size is variable (0.1-7mm) but is generally coarse. In some nodules, subhedral to euhedral clinopyroxenes and micas form a framework of interfering plates and laths. Mica is also observed to enclose smaller clinopyroxenes and accessory minerals poikilitically.

2. These nodules have a similar mineral assemblage to those described above, but are free of the carbonate and oxide phase; apatite is rare. Grain size may vary significantly (0.1-5 mm) within a single thin section. These nodules consist of alternating layers, of variable width (~0.5-6 cm), composed chiefly of euhedral to anhedral clinopyroxene (Di - Sal) and mica (Phl - Bt); some layers are monomineralic. The layered textures (Fig. 2.7) in these nodules is consistent with a cumulate origin.

MINERAL CHEMISTRY

Representative microprobe analyses of important minerals are given in this section. A complete tabulation of microprobe analyses is given in Appendix A. Mineral compositions of clinopyroxene, mica, apatite, feldspar and oxides for the samples from Coulee 29, Milk River Area, Southern Alberta were acquired by wavelength dispersive electron microprobe analyses at the Department of Earth and Atmospheric Sciences, University of Alberta. Clinopyroxene and mica spot analyses were conducted on an ARL SEMQ microprobe. Clinopyroxene and mica line scan, apatite, feldspar and oxide analyses were determined on a JEOL 8900R microprobe. Typical analytical conditions for all probe data as follows: 15kV acceleration potential, 10-12nA beam current, a 1-10 μm beam diameter and a 20 second peak count integration time. Natural minerals were used as standards. Clinopyroxene and mica spot analyses data were corrected with a phi-rho-z program provided by Tracor Northern, data for clinopyroxene and mica line scans, apatite, feldspar and oxides were corrected with a ZAF program provided by JEOL.

---

[1] The old pyroxene nomenclature scheme has been retained for the purpose of this study; some of the pyroxene names used in this study have been formally discarded by the Commission on New Minerals and Mineral Names of the International Mineralogical Association (Morimoto *et. al.*, 1988).

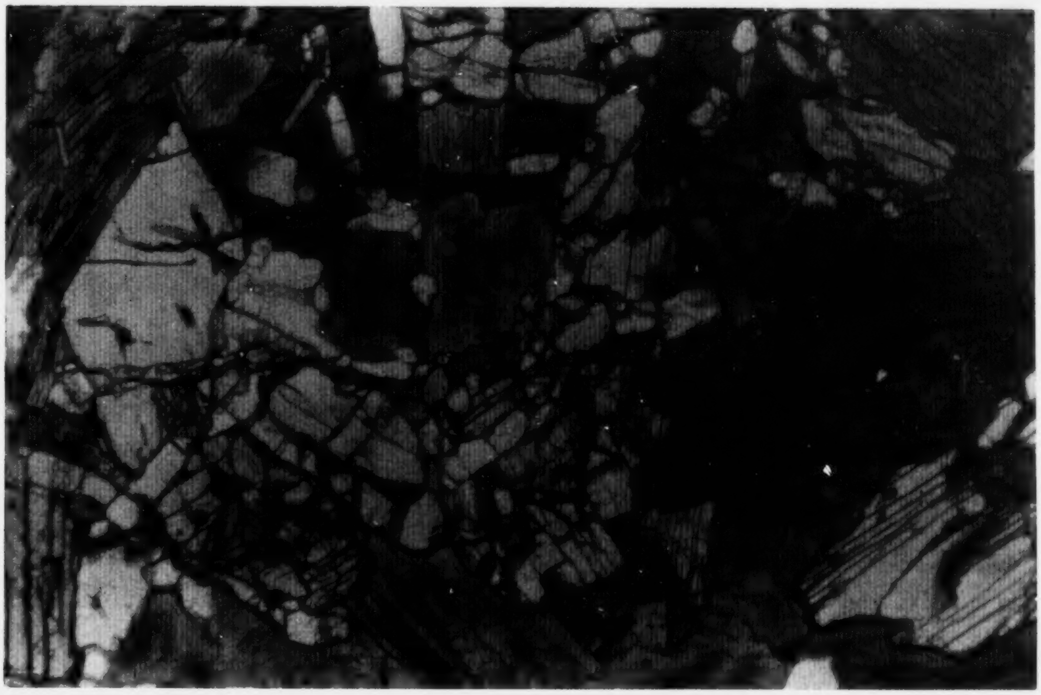


FIGURE 2.6 Photomicrograph of a coarse grained mica-clinopyroxenite nodule. Consists of subhedral to euhedral clinopyroxene and apatite ± carbonate enclosed poikilitically by phlogopite. Plane-polarized light; view is 7x10mm.

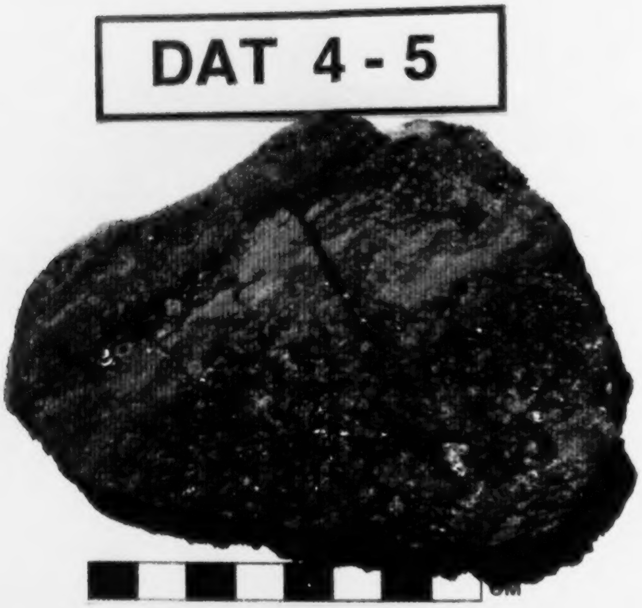


FIGURE 2.7 Phlogopite clinopyroxenite nodule from Coulee 29, consisting of phlogopite and diopside. Note the layered texture and grain size variation.

TABLE 2.1

Representative microprobe analyses of clinopyroxenes

	1 *Core*	2 *Rim*	3 *GCore*	4 *Rim*	5 *Core*	6 *Rim*	7 *GCore*	8 *Rim*	9 *gm*	10 *gm*
SiO_2	54.06	52.92	49.55	53.63	54.06	54.25	53.13	54.52	50.58	51.82
TiO_2	0.24	0.37	0.75	0.23	0.12	0.23	0.40	0.18	0.86	0.72
Al_2O_3	0.83	1.32	4.03	1.23	0.43	0.92	1.20	0.48	3.15	1.93
Cr_2O_3	0.20	0.43	0.05	0.24	0.08	0.00	0.03	0.07	0.00	0.03
Fe_2O_3	0.13	0.92	3.96	0.80	1.04	0.65	2.42	0.19	4.66	2.82
FeO	3.84	4.01	7.09	3.70	2.95	5.01	5.72	3.67	6.28	5.65
MnO	0.10	0.13	0.28	0.12	0.13	0.16	0.23	0.12	0.29	0.29
MgO	17.35	16.26	11.13	16.68	17.65	16.60	15.33	17.40	12.83	14.80
CaO	22.29	22.46	21.70	22.82	22.71	22.33	22.01	22.83	21.13	22.00
Na_2O	0.29	0.36	1.04	0.33	0.23	0.37	0.52	0.27	0.72	0.40
K_20	0.03	0.01	0.03	0.02	0.02	0.01	0.01	0.01	0.47	0.09
Total	99.37	99.17	99.61	99.80	99.42	100.53	100.99	99.73	100.97	100.55
DS	3.625	3.514	2.781	3.562	3.686	3.510	3.321	3.669	2.913	3.227
mg	88.7	85.7	65.0	87.1	89.0	84.1	77.6	89.0	68.6	76.3
Wo	45.0	46.0	47.7	46.1	45.1	44.8	44.5	45.6	44.8	44.9
En	48.7	46.3	34.0	46.9	48.8	46.4	43.1	48.4	37.9	42.0
Fs	6.2	7.7	18.3	7.0	6.0	8.8	12.5	6.0	17.3	13.1

Analyses 1- 4 are phenocrysts from the *olivine minettes*; and 5 - 8 are from the nodules; 9 - 10 are groundmass clinopyroxenes from the *olivine minette*. GCore, greenish core

Clinopyroxene

In the *olivine minettes*, euhedral clinopyroxene phenocrysts and subhedral to euhedral clinopyroxenes in the nodules, plot in the diopside-salite compositional range (Table 2.1 and Fig. 2.8). The clinopyroxene phenocrysts in the *olivine minettes* almost always show complex zoning relationships ranging from normal, reverse and oscillatory within the same sample. In the nodules clinopyroxenes show some zoning and generally cores zone normally to more Fe-rich rims, alternatively they are reversely zoned; occasionally, however, they also display oscillatory zoning. Overall clinopyroxene compositions in the nodules overlap phenocrysts of the associated dikes.

A useful method of discriminating clinopyroxene compositions in the dikes and nodules is to use a cation index (DS) defined by O'Brien *et al.* (1988), which is the sum of the cations enriched in diopsidic compositions (Si+Cr+Mg+Ca) minus the sum of the cations enriched in salitic compositions (Ti+Al+Fe+Mn+Na). Therefore the highest DS values are in diopsidic clinopyroxenes and the lowest values are in salitic compositions. Plots of DS vs. mg [$100*Mg/(Mg+Fe_{total})$] for representative pyroxene analyses from the dikes and nodules show good linear correlations and complete overlap between phenocrystal clinopyroxenes and inclusion clinopyroxenes (Fig. 2.9).

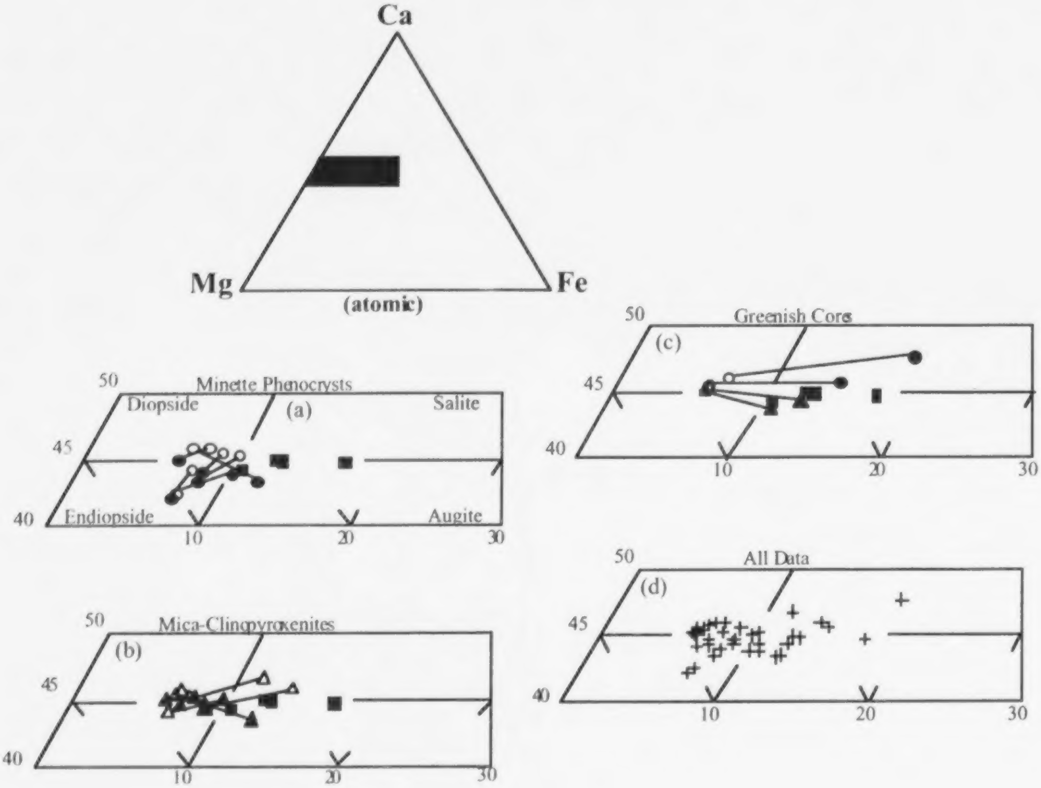


FIGURE 2.8 Compositions of phenocrystal clinopyroxenes in the *olivine minette* and clinopyroxenes in the mica-clinopyroxenites from Coulee 29. Cores (open symbols) and rims (closed symbols) are connected by tie lines. Groundmass clinopyroxene (closed squares).

In both the dikes and the nodules colorless, diopsidic cores zone normally to more Fe-rich rims or diopside may form rims to more Fe-rich colorless cores in reversely zoned crystals (Fig. 2.8). A typical range for clinopyroxenes in the inclusions is $Ca_{45}Mg_{48}Fe_7$ - $Ca_{47}Mg_{42}Fe_{12}$ and $Ca_{43}Mg_{44}Fe_{12}$ - $Ca_{46}Mg_{48}Fe_7$ in the dike phenocrysts.

Clinopyroxenes in the dikes and nodules occasionally contain greenish salitic cores and zone reversely to diopsidic rims (Fig. 2.8). The existence of green, Fe-rich, salitic cores in diopsidic clinopyroxenes in potassic mafic lavas has usually been attributed to magma mixing (Barton *et al.*, 1982; Pe-Piper *et al.*, 1984; Duda and Schmincke, 1985; O'Brien *et al.*, 1988; Macdonald *et al.*, 1992).

Crystals possessing oscillatory zoning occur in both the nodules and as phenocrysts in the dikes, but are much more common in the dikes. The following examples provide an

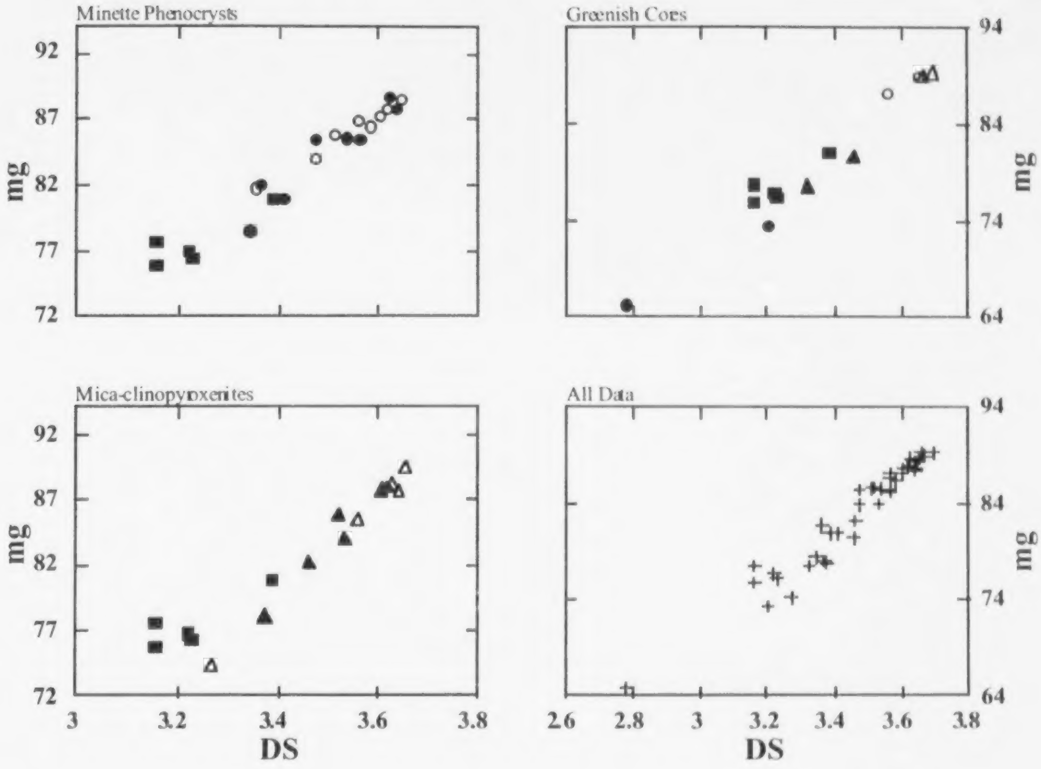


FIGURE 2.9 Variation of mg = [100*Mg/(Mg+Fetotal)] as a function of DS cation index. Where DS = (Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na), O'Brien *et al.* (1988). Cores (closed symbols); rims (open symbols); groundmass clinopyroxene (closed squares).

indication of the complexity and variation from crystal to crystal. The crystal in Fig. 2.10 is from a dike; a heavily resorbed salitic core (light color) surrounded by a Mg-rich zone (dark color) is followed by two salitic layers separated by another diopsidic layer, with the rim again being salitic. The pyroxene in Fig. 2.11 is from a nodule and shows similar complexities. In a study of the mineralogy, chemistry, and origin of the potassic mafic lavas of the Bearpaw Mountains, Macdonald *et al.* 1992 describes clinopyroxenes in minettes that show oscillatory zoning, comparable to those in the minettes and nodules of this study. In an electron microprobe and textural analytical study of clinopyroxenes in minettes and 'mafic phonolites' of the Highwood Mountains O'Brien *et al.* (1988) showed that zoning similar to that in the Bearpaw rocks and the rocks in this study were a result of repeated mixing events between batches of variably fractionated and degassed 'mafic phonolite' magma and primitive undegassed minette magma.

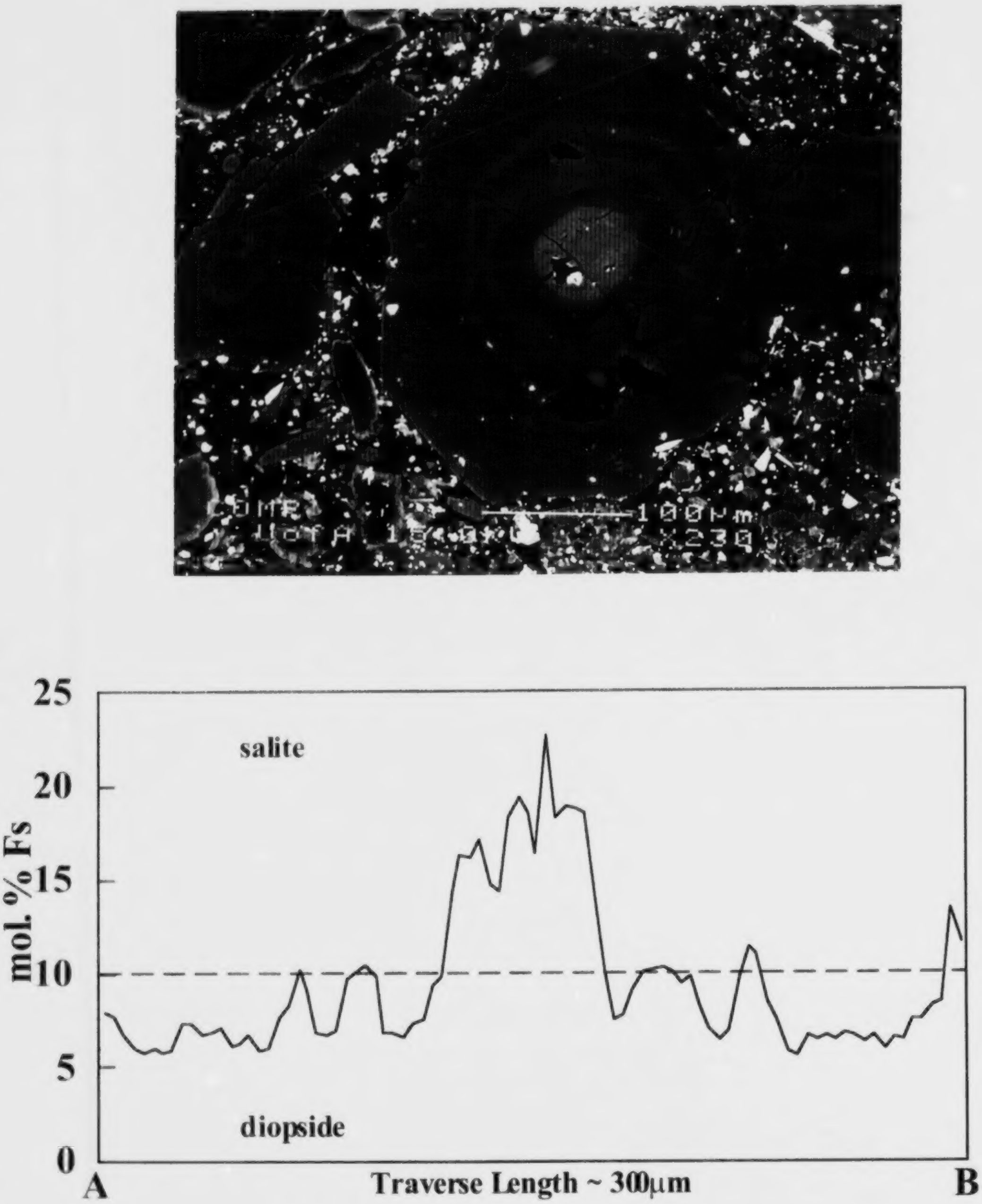


FIGURE 2.10 A back-scattered electron image of a clinopyroxene crystal from the black *olivine minette*. The variation in Fs is shown in the line-scan traverse below.

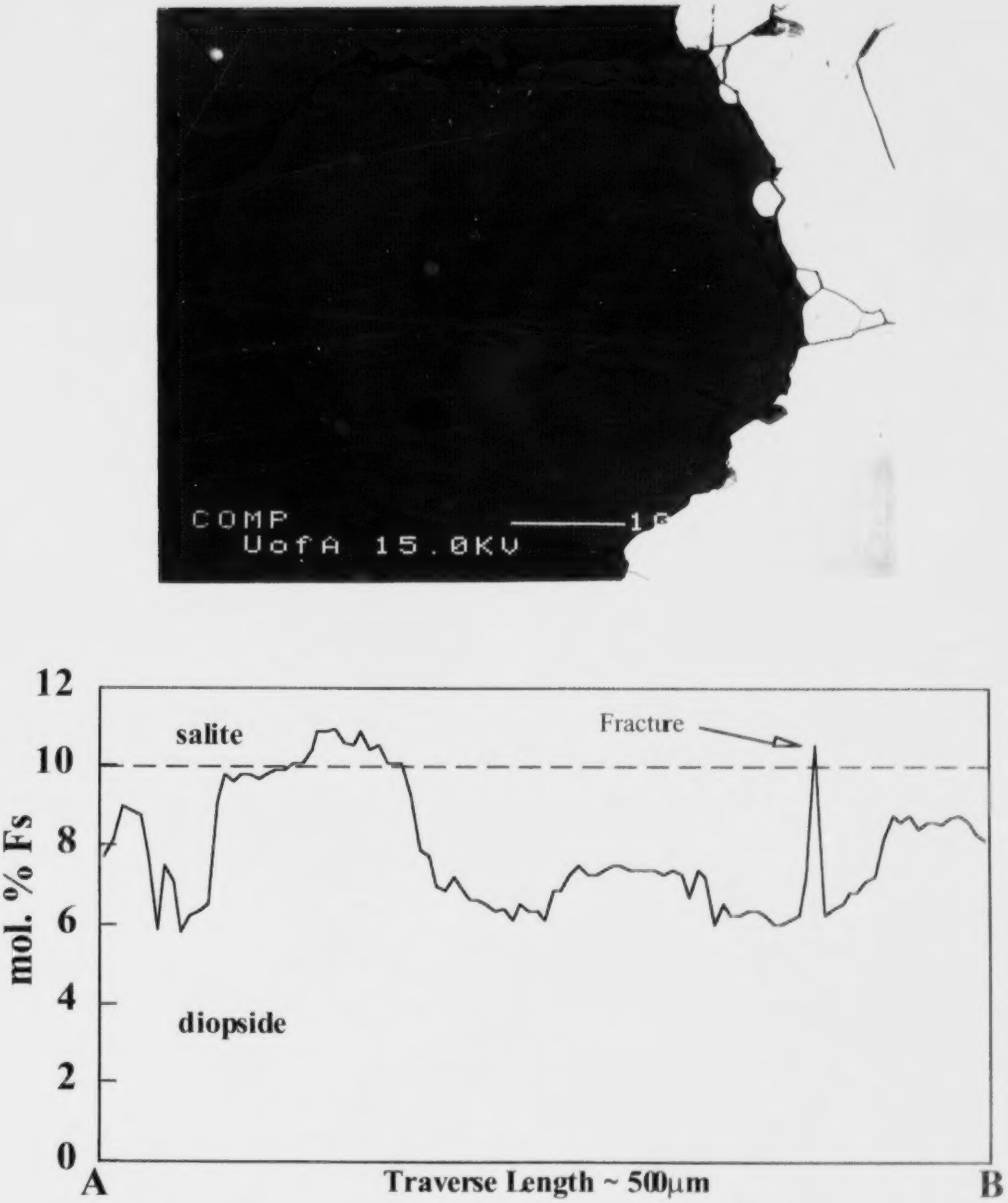


FIGURE 2.11 A back-scattered electon image of a clinopyroxene crystal from a mica-clinopyroxenite inclusion. A line-scan traverse shows the variation in Fs below.

TABLE 2.2

Representative microprobe analyses micas

	1 *Core*	2 *Rim*	3 *Core*	4 *Rim*	5 *Core*	6 *Rim*	7 *Core*	8 *Rim*	9 *gm*	10 *gm*
SiO_2	40.09	38.26	38.73	39.31	40.67	37.96	39.57	39.68	39.08	39.14
TiO_2	1.84	2.97	1.06	2.30	1.48	5.02	1.59	2.60	6.00	6.36
Al_2O_3	12.78	13.96	12.79	13.30	13.12	13.63	13.10	13.81	14.67	13.90
Cr_2O_3	0.13	0.01	0.98	0.12	0.36	0.00	0.37	0.15	0.00	0.00
FeO	9.03	11.91	7.56	10.51	6.48	11.25	6.85	11.07	14.58	15.76
MnO	0.07	0.16	0.01	0.04	0.05	0.01	0.03	0.07	0.24	0.17
MgO	22.51	18.89	23.95	20.94	22.09	17.41	21.89	19.85	13.74	13.67
CaO	0.03	0.03	0.03	0.03	0.00	0.03	0.00	0.00	0.09	0.12
Na_2O	0.41	0.42	0.29	0.46	0.43	0.40	0.38	0.37	0.46	0.60
K_2O	10.12	9.74	10.46	10.07	9.71	9.01	9.80	8.35	8.27	8.31
F	0.94	1.09	1.17	1.44	0.76	0.84	0.00	0.00	1.01	1.13
Cl	0.00	0.02	0.00	0.02	0.03	0.02	0.00	0.01	0.02	0.03
O=F,Cl	0.40	0.46	0.49	0.61	0.33	0.36	0.00	0.00	0.43	0.48
Total	97.55	97.00	96.54	97.93	94.85	95.22	93.56	95.96	97.73	98.71
mg	81.6	73.9	85.0	78.0	85.9	73.4	85.1	76.2	62.7	60.7

Analyses 1 - 4 are from the nodules; and 5 - 8 are phenocrysts from the *olivine minette*; 9 - 10 are groundmass micas from the *olivine minette*.

Phlogopite

In the *olivine minettes* and the associated nodules, mica can form up to 15-20% of the phenocryst assemblage and 30-50% of the mineral assemblage respectively. In both rock types mica (Phl - Bt) exhibit a wide compositional range (Table 2.2). Mica compositions from the nodules and minette dikes overlap extensively along linear trends previously recognized by Mitchell (1986) to be diagnostic of minette rather than lamproite (Fig. 2.12). For minettes, the characteristic mica core-rim compositional trend is one of increasing Fe and Ti at almost constant Al.

In both the *olivine minettes* and nodules, micas are generally normally zoned; the cores with mg $[100*Mg/(Mg+Fe_{total})] = 80-89$, 1-2 wt.% TiO_2, 0.1-1 wt.% Cr_2O_3, and rims with mg = 72-79, 2-6 wt.% TiO_2 and 0.01-0.1 wt.% Cr_2O_3. Groundmass grains are relatively homogeneous and range from mg = 60-65, 5.5-6.5 wt.% TiO_2 and < 0.01 wt.% Cr_2O_3. Fluorine contents are variable but are usually highest in the grain rim (0.35-1.5 wt.% F in rim vs. 0-1 wt. % in the core). Chlorine contents are generally very low (< 0.05 wt.% Cl) and are typically below the detection limit of 0.01 wt.%. Structural formula calculated on the basis of 22 oxygen atoms show that Si + Al sums range from 7.8-8.2, indicating slight tetrahedral Fe^{3+} (or Ti^{4+}, Bachinski and Simpson (1984)) occupancy in some of the micas.

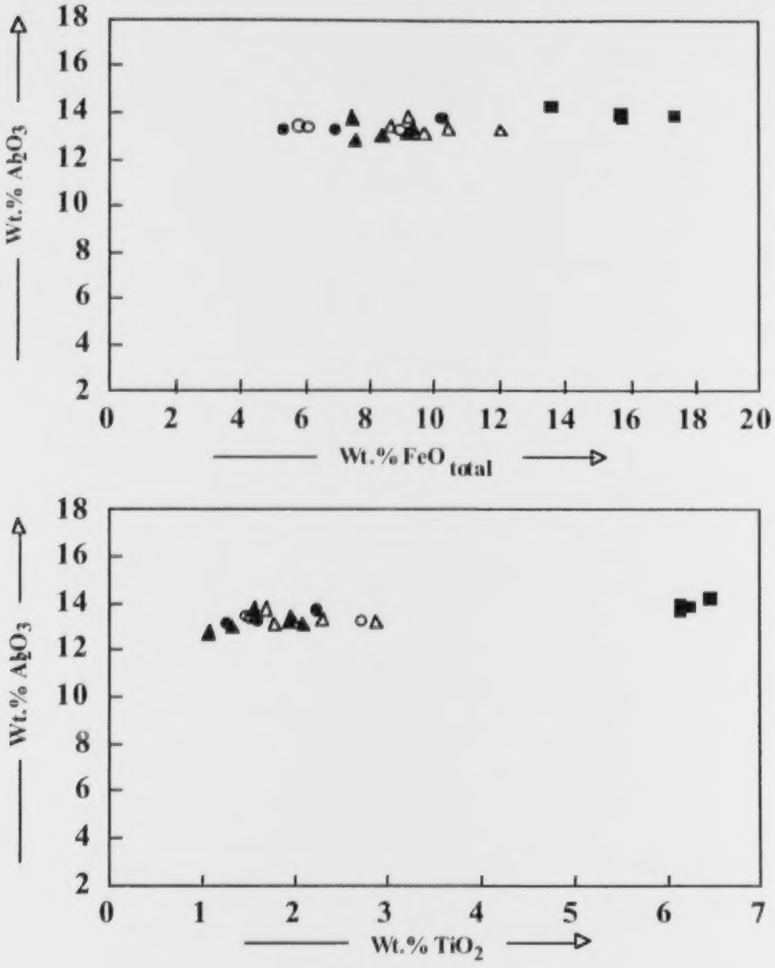


FIGURE 2.12 Variation of FeO (total) and TiO_2 as a function of Al_2O_3 for representative micas from the black *olivine minette* and mica-clinopyroxenites. Cores (closed symbols); rims (open symbols); groundmass mica (closed squares); micas in dikes (circles); micas in nodules (triangles).

In samples of *olivine minette* dike, rare phenocrystal micas with variable and complex zoning occur. In Fig. 2.13 a phlogopite core is surrounded by a more Fe-Ti rich band, a phlogopite band, and a biotitic-phlogopite rim. O'Brien *et al.* (1988) have described similarly complex zoned micas from mixed 'mafic phonolite' of the Highwood Mountains and have attributed this phenomenon to separate episodes of growth in a minette-dominated mixed magma.

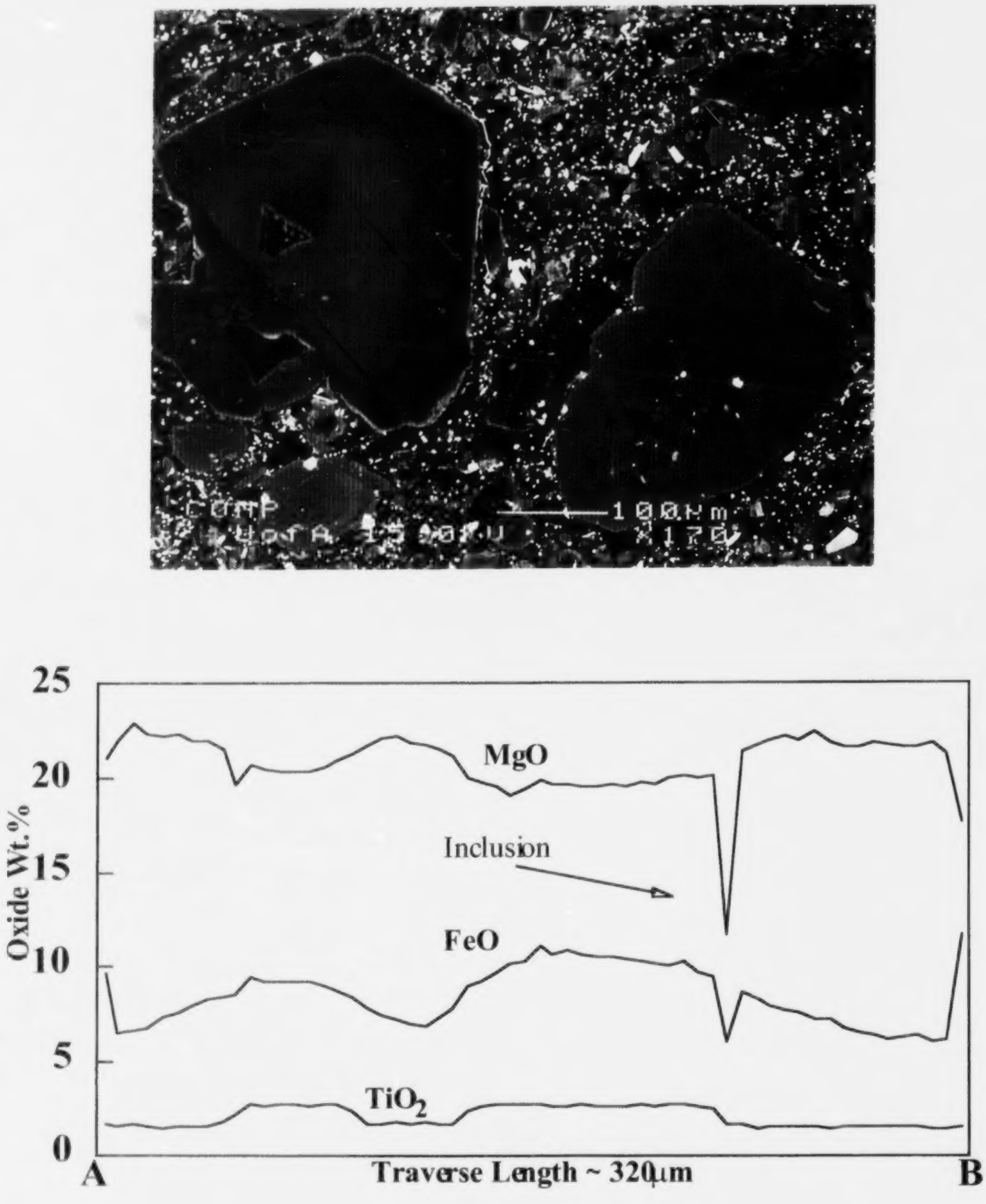


FIGURE 2.13 A back-scattered electron image of a phlogopite phenocryst from the black *olivine minette*. Below is a line-scan traverse showing the variation in MgO wt.%, FeO wt.% and TiO_2 wt.%.

Apatite

Groundmass apatite in the *olivine minette* ranges from hydroxyapatite to flourapatite (Fig. 2.14). Apatites in the phlogopite-clinopyroxenite nodules show a more restricted F/OH range than do the groundmass apatites, and have rim compositions that are within the same range as the crystal cores (Fig. 2.14). Apatite microphenocrysts in the minettes range to more F-rich compositions than apatites within the inclusions. The apatites in the nodules, however, show substantial compositional overlap with microphenocrystal apatites which may indicate crystallization conditions, with respect to volatile contents, similar to those of the minette dikes.

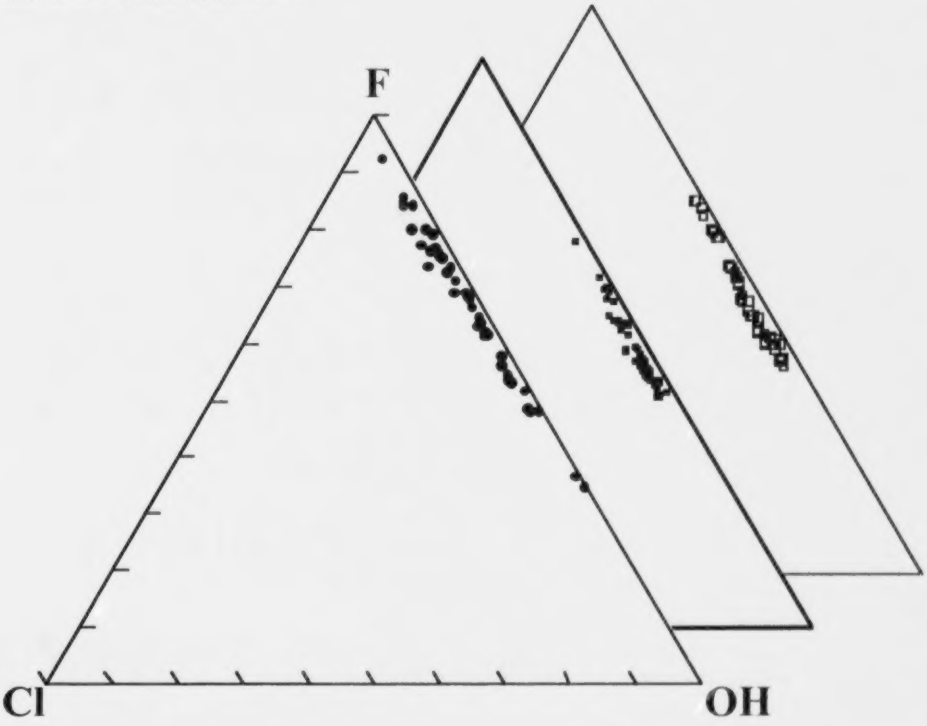


FIGURE 2.14 Apatite compositions within the black *olivine minette* and mica-clinopyroxenites. Plotted in terms of hydroxyl site occupancy, values for OH calculated from stoichiometry. Groundmass and microphenocrystal apatite within the minette (closed circles); Apatite within the nodules, cores (closed squares) and rims (open squares).

In a theoretical fluid/melt partitioning study, Candela (1986) determined that in a system that is exsolving and losing vapor progressively a growing apatite crystal should incorporate progressively less F with time, leading to decreasing Cl/F and OH/F from core to rim. The overall combined compositional trend of the groundmass apatites and the apatites within the nodules may be attributed to such a mechanism.

Feldspar

Sanidine occurs as blades and tablets in the groundmass of the fine grained minettes, forming a large portion of the matrix. It varies in composition from $Or_{49}Ab_{33}An_{18}$ to $Or_{81}Ab_{15}An_4$. Representative analysis are given in Table 2.3.

TABLE 2.3

Representative microprobe analyses of groundmass sanidine

	1	2	3	4	5	6	7	8
SiO_2	62.54	65.10	61.70	63.63	62.07	64.30	64.55	63.71
Al_2O_3	18.63	18.62	20.04	19.49	17.38	18.61	18.91	19.95
FeO	0.54	0.54	1.03	0.63	1.33	0.80	0.58	0.54
MnO	0.03	0.00	0.00	0.00	0.02	0.00	0.07	0.00
CaO	0.84	0.41	0.62	0.60	4.16	0.33	0.30	1.01
BaO	0.63	0.00	3.00	0.06	0.14	0.47	0.56	0.90
Na_2O	1.55	3.33	3.56	3.74	4.15	3.87	3.98	4.92
K_2O	13.90	11.56	9.45	11.07	9.57	10.51	10.38	8.60
Total	98.66	99.56	99.40	99.22	98.82	98.89	99.33	99.63
XAn	0.04	0.02	0.03	0.03	0.18	0.02	0.01	0.05
XAb	0.14	0.30	0.33	0.33	0.32	0.35	0.36	0.43
XCs	0.01	0.00	0.06	0.00	0.00	0.01	0.01	0.02
XOr	0.81	0.68	0.58	0.64	0.49	0.63	0.62	0.50

All analyses are groundmass sanidine from the *olivine minette*.

Oxides

Oxides are present in the minettes but are rare in the suite of nodules that were studied. The oxides in the minettes are dominantly titanomagnetite, which occurs as an extremely fine-grained groundmass phase. Compositions range from 3.3 wt.% Cr_2O_3, 0.17 wt.% MgO, 0.5 wt.% Al_2O_3 and 9 wt.% TiO_2 to 0.3 wt.% Cr_2O_3, 0.03 wt.% MgO, 0.2 wt.% Al_2O_3 and 10 wt.% TiO_2 (Table 2.4).

Chromite has also been observed in the minettes as inclusions in olivine relict phenocrysts, rather than in the groundmass.

TABLE 2.4

Representative microprobe analyses of oxides

	1	2	3	4
	gm	***gm***	***i***	***i***
SiO_2	0.202	0.233	0.066	0.182
TiO_2	8.899	9.724	0.841	0.854
Al_2O_3	0.499	0.192	4.427	7.122
Cr_2O_3	3.301	0.261	58.992	53.136
Fe_2O_3	84.050	88.311	20.770	27.769
MnO	1.710	0.418	0.307	0.390
MgO	0.171	0.032	14.074	11.390
NiO	0.035	0.090	0.164	0.211
Total	98.867	99.261	99.641	101.054

All analyses are from the *olivine minette.* gm, groundmass phase; i, inclusions within altered olivine phenocrysts.

Olivine and Analcime (or Pseudoleucite)

Other, altered, phases include: Olivine that has been replaced by carbonate, chlorite and possibly a fibrous amphibole and talc. Analcime (or pseudoleucite) is present as well. In a study of analcime in the Colima minettes, Luhr and Kyser (1989) showed that leucite may rapidly alter to analcime, even in freshly erupted lavas.

Chapter 3

Whole - Rock Geochemistry

INTRODUCTION

Samples of the Eocene Milk River area minette suite ranges in composition from primitive (>13 wt.% MgO and >600 ppm Ni) to more evolved (~ 5 wt.% MgO and ~130 ppm Ni). Members of the suite have high K_2O, Sr, Ba contents and are light rare earth element enriched and show depletions, relative to lamproite, in Ti, Nb, Ta, Zr and Hf. Minettes similar to these have been attributed to small degrees of partial melting of a garnet peridotite mantle source (Roden, 1981; O'Brien, 1991). This derivation is consistent with the presence of phlogopite-garnet peridotite xenoliths in the Thumb minette volcanic plug, Navajo volcanic field, Colorado Plateau province, Arizona/New Mexico (Ehrenberg, 1982).

Ultramafic nodules that occur in some of the Milk River minettes could represent cognate cumulates and provide evidence for the importance of crystal fractionation during the evolution of magmas related to the Sweetgrass Hills Igneous Complex. It is important to determine whether crystal fractionation alone could have generated the entire spectrum of these minette magmas.

The mechanisms that produced the Milk River minette magmas are probably similar to those in other compositionally similar systems. In particular, evidence for the importance of differentiation in magma chambers can be found in the cumulate-textured xenoliths found in these magmas. For example, in the Highwood mountains where primitive minettes and more evolved mafic phonolites have erupted, phlogopite-clinopyroxenite and biotite-clinopyroxenite, respectively (O'Brien, 1991) have been found. Hermes and Cornell (1981) describe accumulate biotite-phlogopite dunites, peridotites and abundant biotite-phlogopite clinopyroxenites from lavas of Mt. Vesuvius, Italy. In central Italy leucitites have erupted cumulates that include a pyroxenite-gabbro-anorthosite-monzonite-syenite-foidal series, and an olivine pyroxenite-phlogopite pyroxenite series (Giannetti, 1981).

WHOLE-ROCK GEOCHEMISTRY

The whole rock major and selected trace element chemistry of nine minettes, one diorite porphyry and seven mica-clinopyroxenite inclusions were determined. The minettes and diorite porphyry comprise the entire range of rock types observed in the Milk River exposures. Representative results are given for the lavas in Table 3.1a and for the inclusions in Table 3.1b. More complete tabulations are given in Appendix C.

Whole rock analyses on powdered Milk River samples were carried out by Activation Laboratories in Ancaster, Ontario. Major element concentrations were determined on ~ 3 gram samples by X-ray Fluorescence spectroscopy (fusion). Trace element concentrations were determined using a combination of Inductively Coupled Plasma emission spectrometry (fusion), XRF (with pressed powder pellets of ~ 6 grams) and Instrumental Neutron Activation Analyses (~ 2 gram samples). Detection limits reported by Activation Laboratories as follows: to 0.01% for XRF (fusion), to 2ppm for ICP (fusion), 2-5ppm for XRF with pressed powder pellets and to 2ppb-10ppm for INAA.

Major Elements

The Milk River minettes display the following compositional ranges: 43-52 wt.% SiO_2, 1-1.5 wt.% TiO_2, 9-12 wt.% Al_2O_3, 8-10 wt.% Fe_2O_3T, 5-14 wt.% MgO, 7-8 wt.% CaO, 4-9 wt.% K_2O, 1-2 wt.% P_2O_5 and 1-2 wt.% Na_2O. The average composition for the Milk River minettes is comparable to the average composition of the Highwood and Bearpaw minettes (Table 3.1a). The Milk River minettes range from primitive *olivine minette* to more evolved *minette* and *felsic minette*. Trace elemental variations in general follow these major-element trends.

MgO variation diagrams showing the compositional relationships between major elements in the Milk River minettes and minettes from the Highwood and Bearpaw mountains are illustrated in Fig. 3.1. The variations displayed by the Milk River samples are similar to those of the Highwood and Bearpaw minettes. Fig. 3.1 also shows the compositional relationships between the Milk River minettes and mica-clinopyroxenite nodules from Coulee 29.

Elements that vary systematically with increasing evolution as indicated by decreasing MgO include Al, Fe, Na, Si, Ca, P and K whereas variations in Ti are more difficult to distinguish. The compositions of the mica-clinopyroxenite nodules lie on

TABLE 3.1a

Major and Trace Element Compositions of the Milk River Area Rocks, and Average Compositions of the Highwood and Bearpaw Mountains minettes and the Smoky Butte lamproites

Sample	OC7-1	OC8-16	RAB90 Au24-1	MR92-09	G70-11-7	MR92-01	ave. Milk River minette	ave. Highwood Mts. minette	ave. Bearpaw Mts. minette	ave. Smoky Butte lamproite
Type	*olivine minette*	*olivine minette*	*olivine minette*	*minette*	*felsic minette*	diorite porphyry				
Location	Coulee 29	Coulee 29	Pakowki Gulch	Black Butte	49th Parallel	Miners Coulee	(n=9)			
SiO_2	48.26	49.98	45.34	52.09	43.15	60.71	47.23	48.02	50.17	51.53
TiO_2	1.01	0.98	1.02	0.92	1.5	0.46	1.05	0.65	0.72	5.28
Al_2O_3	9.74	9.96	9.22	10.12	11.52	17.42	10.06	13.15	11.16	9.12
Fe_2O_3	9.59	9.07	10	7.03	7.78	5.51	8.76	8.61	9.25	5.76
MnO	0.11	0.12	0.14	0.12	0.12	0.14	0.13	0.15	0.16	0.07
MgO	11.76	11.43	13.63	8.41	5.24	1.57	10.43	8.29	10.75	7.74
CaO	8.01	7.73	8.02	7.5	7.4	6.18	7.47	8.67	7.57	4.89
K_2O	4.72	4.89	4.44	6.4	8.85	2.88	5.78	5.75	4.13	7.00
P_2O_5	1.1	1.03	1.02	1.02	1.53	0.28	1.07	0.85	0.62	1.87
Na_2O	1.62	1.82	1.3	2.21	1.44	3.99	1.58	2.24	2.61	1.45
LOI	3.45	2.48	4.64	3.19	6.82	1.28	4.30	3.26	2.10	3.44
TOTAL	99.37	99.49	98.77	99.01	95.35	100.42	97.86	99.63	4.52	98.14
Cr	890	750	960	494	451	20	748	297	553	434
Ni	450	380	664	127	133	-5	369	125	269	----
Co	50	46	57	33	40	10	46	53	62	30
Sc	20	20	23.6	20	10.2	8.9	20	25	20	14
V	180	170	184	146	145	64	170	128	191	----
Cu	90	85	----	----	----	----	----	92	55	----
Pb	15	10	----	----	----	----	----	31	22	----
Zn	95	60	116	103	101	86	104	84	88	----
In	----	----	<2ppb	<2ppb	<2ppb	<2ppb	----	----	----	----
W	<1	<1	<3	<3	<3	<3	----	----	----	----
Mo	INT	INT	----	----	----	----	----	----	----	----
S	----	----	<1(%)	<1(%)	<1(%)	<1(%)	----	----	----	----
As	<1	1	<2	2.5	<2	<2	----	----	----	----
Se	<0.5	<0.5	----	----	----	----	----	----	----	----
Sb	<0.1	0.1	<1	0.27	0.17	0.17	----	----	----	----
Ag	0.1	0.2	----	----	----	----	----	----	----	----
Ir	<1ppb	<1ppb	<5ppb	<5ppb	<5ppb	<5ppb	----	----	----	----
Au	3ppb	3ppb	<5ppb	<5ppb	7ppb	<5ppb	----	----	----	----
Hg	<1	<1	<1	<1	<1	<1	----	----	----	----
Rb	178	190	146	184	366	70	205	141	193	----
Cs	3.2	3	1.2	2.8	1.6	0.8	2.6	----	31.5	----
Ba	1586	1586	3239	3821	3877	884	2962	4415	2731	8280
Sr	1303	1145	993	1905	2179	1247	1378	1300	971	----
Ga	6	9	14	16	18	23	12	15	----	----
Ta	0.5	<0.3	0.48	0.59	0.87	0.58	0.54	----	0.69	6.11
Nb	13	13	12	14	24	10	14	27	10	----
Hf	5.4	5.3	5.55	7.69	9.38	3.07	6.46	----	2.35	45.76
Zr	260	245	225	288	302	136	256	121	122	----
Y	14	14	16	22	23	13	19	17	18	----
Th	7.4	6.9	7	10.1	37.1	8.7	11.2	9.7	6.5	5.8
U	2.4	2.3	2.55	2.56	23.6	2.34	4.91	2.06	2.20	----
La	37.5	35.9	38.8	54.1	101	46.5	47.68	43.77	26.86	360.90
Ce	76	72	84.6	117	224	85.6	103.14	83.07	65.77	786.00
Nd	37	35	42.9	54.5	92.3	32.3	47.79	42.50	34.64	----
Sm	7.3	7.1	8.21	10	14.6	6	9	8	6	32
Eu	1.98	1.92	2.18	2.62	3.38	1.89	2.30	2.09	1.50	7.95
Tb	0.7	0.6	0.63	0.89	0.91	0.65	0.75	----	0.65	1.86
Dy	----	----	3.06	3.94	4.01	3.28	3.83	3.67	----	----
Yb	1.14	1.17	1.03	1.33	0.83	1.3	1.2	1.4	1.5	1.6
Lu	0.19	0.18	0.176	0.186	0.111	0.185	0.178	0.194	0.185	----
Cl	----	----	<100	<100	<100	<100	----	190	----	----
Br	<0.5	<0.5	<0.5	3	6.6	<0.5	----	----	----	----
Be	5	5	----	----	----	----	----	3.6	----	----
La/Yb	22	21	25	27	82	24	28	22	18	156
K_2O/Na_2O	2.91	2.69	3.42	2.90	6.15	0.72	3.83	3.87	1.83	4.81
K/Al	0.52	0.53	0.52	0.68	0.83	0.18	0.62	0.48	0.40	0.83
Peralkalinity	0.80	0.83	0.75	1.04	1.04	0.56	0.88	1.17	0.99	1.73

Total Fe expressed as Fe_2O_3; Major Elements in weight %, All Trace Elements in ppm unless otherwise stated. Averages for the Highwood, Bearpaw minettes and Smoky Butte lamproites were calculated from values given in O'Brien (1988), Macdonald *et al.* (1992) and Mitchell *et al.* (1987) respectively.

TABLE 3.1b

Major and Trace Element Compositions of the Milk River Area Mica-Clinopyroxenites; Coulee 29

Sample	DAT4-5	OC8-6	OC8-9	OC8-12	OC8-17	AU26-5	AU26-10	ave. Milk River
Type	Phl-Cpxite	Phl-Cpxite	Phl-Cpxite	Phl-Cpxite	Phl-Cpxite	Phl-Cpxite	Phl-Cpxite	Phl-Cpxite
Location	Coulee 29	Coulee 29	Coulee 29	Coulee 29	Coulee 29	Coulee 29	Coulee 29	(n=7)
SiO_2	47.67	43.5	40.47	43.08	41.56	41.05	35.93	41.89
TiO_2	0.72	1	0.92	0.82	1.17	1.07	1.12	0.97
Al_2O_3	5.48	6.18	6.02	6.79	7.35	7.7	7.54	6.72
Fe_2O_3	6.51	7.3	6.88	7.42	9.58	8.01	8.37	7.72
MnO	0.1	0.11	0.08	0.17	0.12	0.16	0.23	0.14
MgO	19.36	18.32	16.38	17.81	16.32	15.71	12.77	16.67
CaO	14.09	14.36	16.95	14.1	13.6	13.29	17.22	14.80
K_2O	3.74	4.73	4.12	4.75	4.6	4.72	4.28	4.42
P_2O_5	0.4	2.96	5.45	0.21	3.06	1.59	3.65	2.47
Na_2O	0.34	0.27	0.35	0.32	0.41	0.01	0.32	0.29
LOI	0.89	0.79	0.98	3.28	1.68	5.59	8.26	3.07
TOTAL	99.3	99.52	98.6	98.75	99.45	98.9	99.69	99.17
Cr	510	280	18	110	3600	404	57.9	711.4
Ni	160	190	66	320	98	245	110	170
Co	42	48	55	46	65	49.9	50	51
Sc	29	23	25	26	27	22.3	20.7	24.7
V	----	----	----	----	----	----	----	----
Cu	----	----	----	----	----	----	----	----
Pb	----	----	----	----	----	----	----	----
Zn	20	22	28	39	42	94	98	49
In	----	----	----	----	----	----	----	----
W	<1	<1	<1	<1	<1	<1	3	----
Mo	<2	<2	<2	<2	<2	<2	<2	----
S	----	----	----	----	----	----	----	----
As	<1	<1	2	<1	2	<1	<1	----
Se	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	----
Sb	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	----
Ag	<2	<2	<2	<2	<2	<2	<2	----
Ir	<1ppb	<1ppb	<1ppb	<1ppb	<1ppb	<1ppb	<1ppb	----
Au	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	----
Hg	<1	<1	<1	<1	<1	<1	<1	----
Rb	185	216	198	182	191	181	163	188
Cs	1.3	1.1	1.3	1.3	1.6	1.8	1.8	1.5
Ba	1378	1368	1369	1686	1478	3476	3245	2000
Sr	360	574	1127	313	578	682	727	623
Ga	<5	<5	<5	<5	<5	8	9	----
Ta	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	----
Nb	6	6	7	6	7	<2	5	----
Hf	0.6	0.5	0.5	0.8	0.8	1.5	1.5	0.9
Zr	23	15	15	14	22	64	58	30
Y	6	10	12	6	11	9	18	10
Th	0.2	0.2	1.5	0.1	0.7	1.5	2.3	0.9
U	0.2	<0.1	0.2	<0.1	0.1	0.4	0.5	----
La	5.2	17.9	40.3	4.6	19.5	15.3	30.8	19.1
Ce	14	46	95	11	49	34	72	46
Nd	9	30	53	7	31	21	41	27
Sm	2.1	5.8	10	1.7	6.2	4.35	8.81	5.57
Eu	0.55	1.49	2.6	0.46	1.71	1.08	2.2	1.4
Tb	0.2	0.5	0.8	0.2	0.6	0.4	0.7	0.5
Dy	----	----	----	----	----	----	----	----
Yb	0.16	0.39	0.66	0.28	0.6	0.49	0.87	0.49
Lu	0.03	0.06	0.1	0.04	0.09	0.08	0.12	0.07
Cl	----	----	----	----	----	----	----	----
Br	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	----
Be	----	----	----	----	----	----	----	----
La/Yb	22	31	41	11	22	21	24	25
K_2O/Na_2O	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91
K/Al	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Peralkalinity	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

Total Fe expressed as Fe_2O_3; Major Elements in weight %, All Trace Elements in ppm unless otherwise stated.

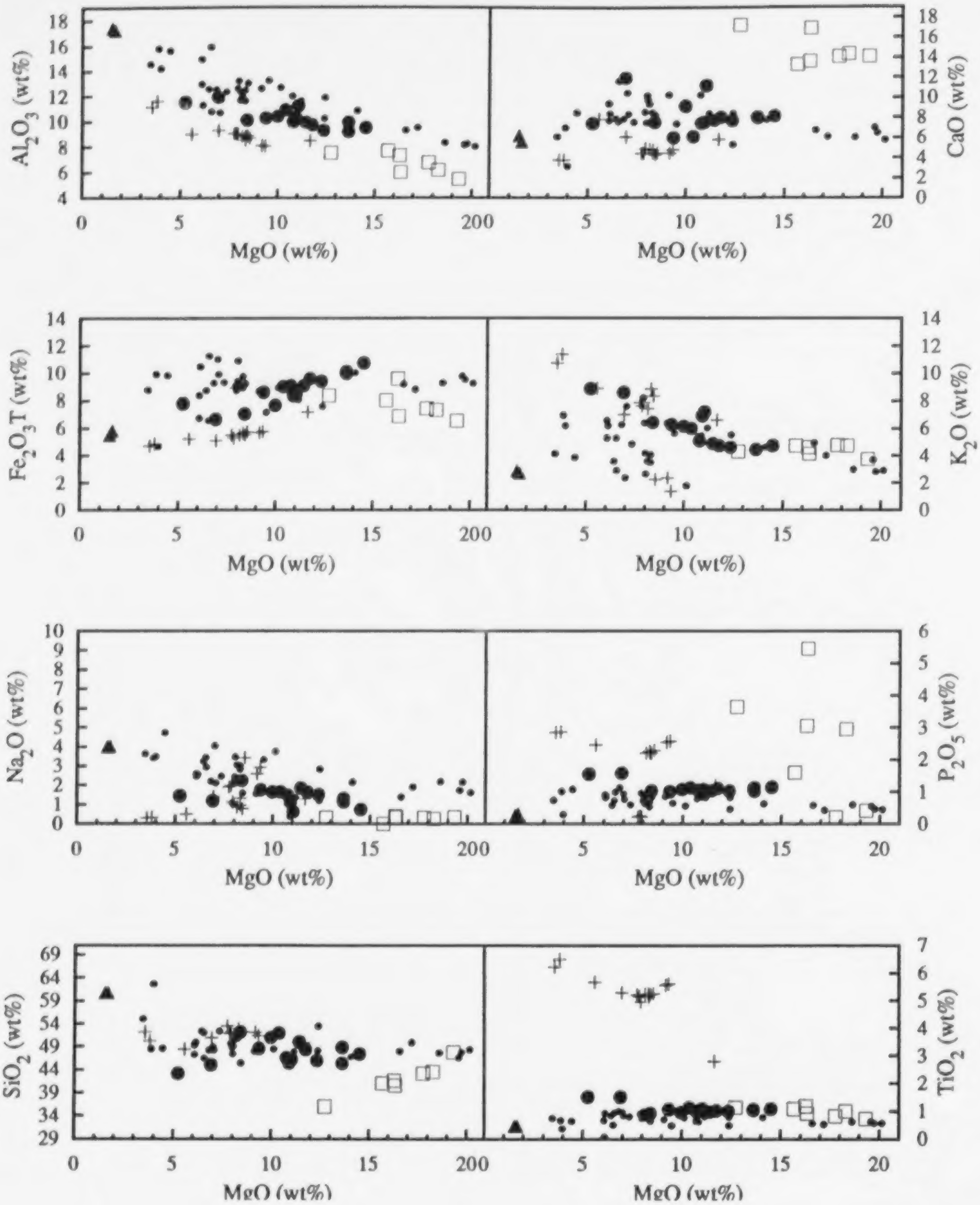


FIGURE 3.1 MgO variation diagrams showing the compositions of the Milk River minettes (large closed circles) compared with minettes from the Highwood and Bearpaw Mountains (small dots; O'Brien 1988, and Macdonald *et al.* 1992 respectively), and the Smoky Butte lamproites (small crosses; Mitchell *et al.* 1987). Closed triangle is a porphyritic diorite from the Milk River Area. Open squares are Mica-Clinopyroxenites from Coulee 29 in the Milk River Area, Southern Alberta.

extrapolations of the trends for Al_2O_3, CaO, and SiO_2. This is consistent with the nodules being cumulates, extracted from the evolving parental magma.

In Table 3.1a, the average Milk River minette is very similar to the average minettes from the Highwood and Bearpaw mountains, with the exception of slight differences in Si, Al, Ti and Na. The average Milk River minettes do however show a distinct contrast to the Smoky Butte lamproite, the Milk River minettes are much lower in TiO_2 and K_2O, and higher in MgO and CaO.

Trace Elements

The trace-element concentrations of the Milk River minettes, mica-clinopyroxenites and comparable rocks are listed in Table 3.1a and 3.1b. Trace-element variations in the Milk River minettes are more pronounced than the variations in major-element compositions. Some trace-elements show systematic variations with MgO. For example in going from the primitive *olivine minette* to the more evolved *minette* and *felsic minette*, Ni decreases by a factor of ~5 and Cr by a factor of ~2. LREE elements generally increase whereas changes in HREE are more subtle.

Fig. 3.2 illustrates the compositional relationships between various trace-elements and MgO in the MR minette suite, mica-clinopyroxenites and the Highwood and Bearpaw minettes. The variation displayed by the Milk River minettes is similar to that shown by the Highwood and Bearpaw minettes, with the exception of enrichments in Zr in the former. REE patterns (Fig. 3.3a) for the Milk River minettes are subparallel (except G70-11-7 and MR92-01) and the samples show a decrease in their degree of LREE enrichment with increasing Si, with the exception of the *felsic minette* and the diorite porphyry. The mica-clinopyroxenite nodules show near parallel LREE enriched patterns (Fig. 3.3b) with an overall depletion in REE compared to the minettes. In both the minettes and nodules, no negative Eu anomaly is observed. This feature is most likely a result of the restriction of feldspar to the groundmass of the minettes and lack of feldspar in the nodules, which indicates that no feldspar fractionation occurred in the minettes.

In terms of trace-elements the average Milk River minette is similar to the average Highwood and Bearpaw minette with the exception of slight enrichments in Zr and Hf in the former. As with the major elements, the Milk River minettes differ from the Smoky Butte lamproite on the basis of much lower Ta, Hf, Ba and REE contents.

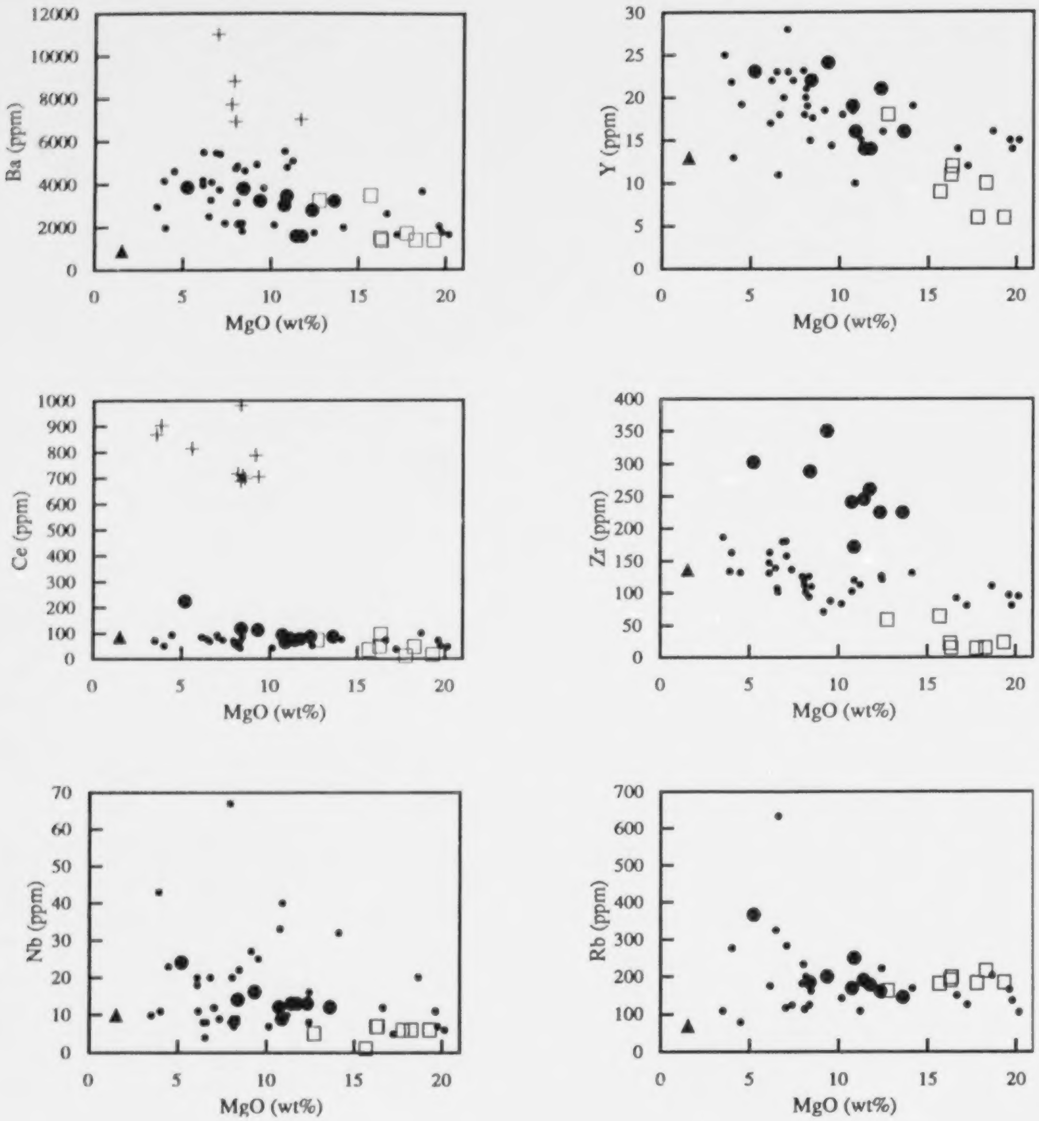


FIGURE 3.2 MgO variation diagrams for selected trace elements. Large closed circles, Milk River minettes compared with minettes from the Highwood and Bearpaw Mountains (small dots; O'Brien 1988 and Macdonald *et al.* 1992 respectively), and the Smoky Butte lamproites (small crosses; Mitchell *et al.* 1987). Closed triangle is a porphyritic diorite from the Milk River Area. Open squares are Mica-Clinopyroxenites from Coulee 29 in the Milk River Area, Southern Alberta.

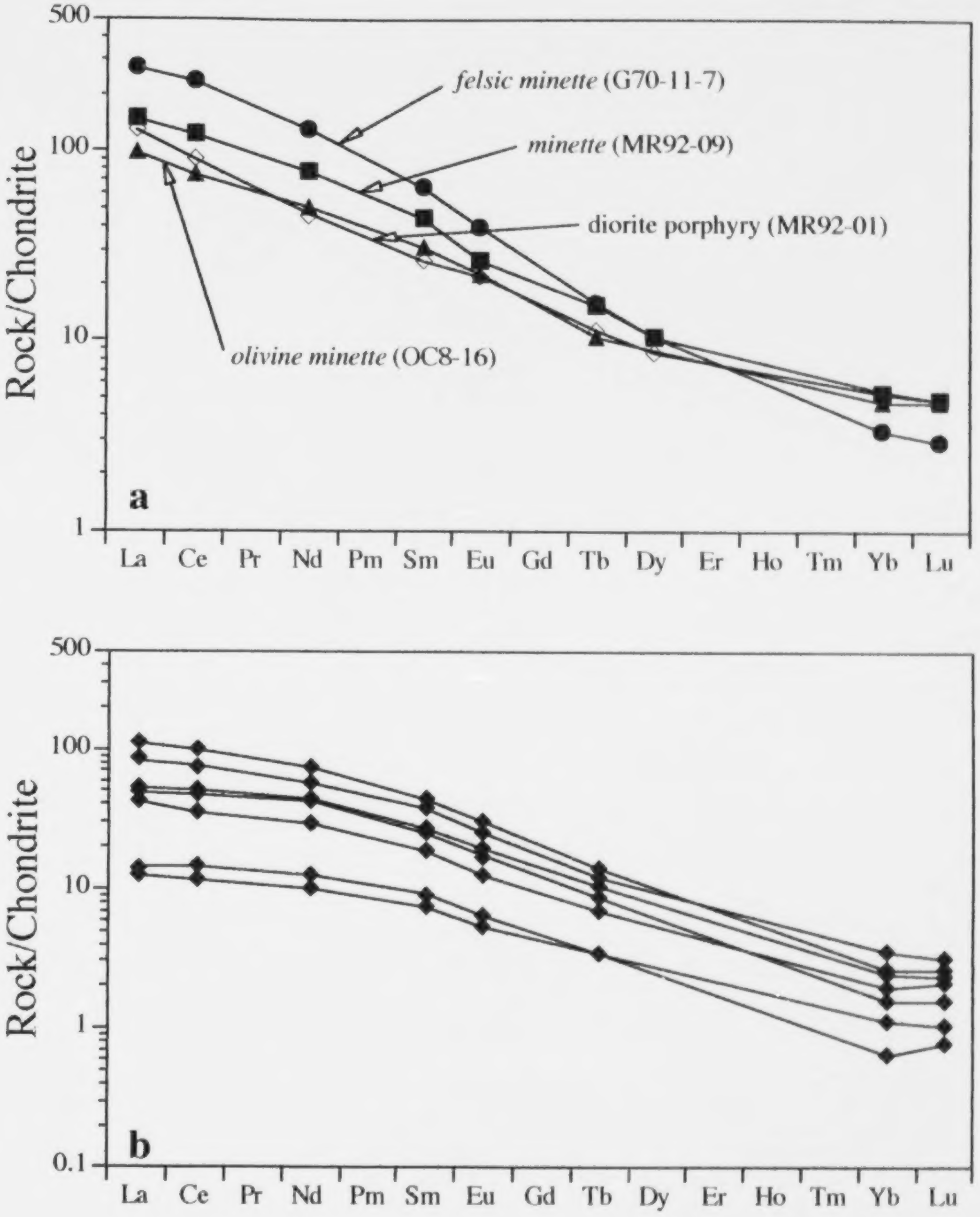


FIGURE 3.3 Chondrite-normalized (chondrite from Taylor and McLennan 1985) rare-earth-element patterns; a) Three Milk River minette samples and a diorite porphyry sample spanning the entire range in major element composition; b) Seven mica-clinopyroxenite samples from Coulee 29.

CONCLUSIONS

The Milk River minettes are similar in major and trace-element compositions to the minettes found in the Highwood and Bearpaw Mountains igneous systems. They are, however, markedly different from the Smoky Butte lamproites. The Milk River minettes show apparent systematic variations in several major and trace-elements with respect to MgO that may have resulted by crystal fractionation of minerals that occur as phenocrysts and cumulate nodules, from compositions analogous to the presumably parental *olivine minette*.

Chapter 4

Isotope Systematics

INTRODUCTION

Potassic to ultrapotassic mafic magmas ranging from leucitites to minettes to lamproites form a volumetrically insignificant, but important group of igneous rocks. Some of these magmas are the rare products of magmatism above active subduction zones, where they are associated intimately spatially and temporally with calc-alkaline suites. Examples include leucitites from the Sunda arc of Indonesia (Wheller *et al.*, 1987; Edwards *et al.*, 1994) and the Pliocene to Recent minette volcanics of the Mexican volcanic belt (eg. Luhr and Carmichael, 1981; Wallace and Carmichael, 1992), where they show a close association with calc-alkaline rocks (Luhr *et al.*, 1988). Others may occur during or after continental collision, after ocean basin closure. The post-collisional potassic magmatic activity may then continue and grade into extension-related alkalic intracontinental plate volcanism. The Roman province of Italy is related to such a setting (Keller, 1983) where trachybasalts to trachytes, leucitites, leucite- and kalsilite bearing melilites and minettes occur. Other examples of ultrapotassic magmatism occur in intracontinental extensional settings. Examples include parts of the East African Rift (Thompson 1985) as well as lamproites of West Kimberley (Varne 1985) and leucitites of New South Wales (Nelson *et al.*, 1986).

In late Cretaceous to Eocene times, much of the Wyoming Province was affected by Laramide events that included extensive, eastward propagating magmatism (Eggler *et al.*, 1992). The rocks contain associated potassic and calc-alkaline suites, similar to those found in subduction related settings. Present models relate Laramide magmatism and tectonics to subduction of one or more shallow plunging slabs of the Farallon plate (Lipman *et al.*, 1971; Bird, 1984).

The primary focus of this chapter is to present isotopic data for the Eocene minettes and mica-clinopyroxenite inclusions in the Milk River area of southern Alberta. These isotopic data will be used in Chapter 5 to constrain possible petrogenetic models for these magmas. In addition, these isotopic data are used to test the possibility that the mica-clinopyroxenite inclusions from Coulee 29 have a cognate relationship with the Milk River minettes, which requires that the inclusions and the minettes have indistinguishable isotopic compositions.

MILK RIVER SAMPLES

The Milk River mafic alkalic exposures represent northern outliers of the Eocene age Sweetgrass Hills igneous complex of Montana. The exposures occur as dikes, sills and plugs as well as extrusive rocks. The minettes (49 Ma, Baadsgaard *et al.*, 1961; 50±0.5 Ma, Kjarsgaard and Davis, 1994) are the dominant magma type; containing phlogopite, diopside, ± olivine phenocrysts. The mica-clinopyroxenite nodules, collected at Coulee 29, contain phlogopite, diopside and apatite.

The 16 Milk River samples chosen for whole rock isotopic analysis span all of the exposures in the Milk River area of southern Alberta. Sr, Nd, and Pb isotopic compositions of mineral separates from four samples (1 minette dike and 3 mica-clinopyroxenite nodules; all from Coulee 29) were also analyzed to test the possibility of a cognate origin of the inclusions. The samples analyzed consist of 9 minettes, 5 mica-clinopyroxenites and the diorite porphyry. A complete list of rock types, sample numbers and mineral separates is given in the Appendix.

Analytical Results

Analytical methods and results of Rb-Sr, Sm-Nd and Pb-Pb isotopic analyses are given in Appendix D. Initial ratios for Sr and Nd were calculated for 50 Ma based on a K-Ar age of 49 Ma for a minette dike from southern Alberta (Baadsgaard *et al.*, 1961) and K-Ar ages of 50 - 53 Ma for various units from the Sweetgrass Hills, Montana (Marvin *et al.*, 1980).

The range in whole rock $^{87}Sr/^{86}Sr$ (0.70631 - 0.70743) of the 9 minette samples display some overlap with (0.70566 - 0.70660) those obtained on the 5 mica-clinopyroxenite samples from Coulee 29 (Fig.4.1 and 4.2). There is no systematic difference between the $(^{87}Sr/^{86}Sr)_i$ of the mineral separates and the whole rocks, consistent with minimal disequilibrium in the Rb/Sr system. Based on an apatite separate from sample OC8-6 (mica-clinopyroxenite) mineral/whole rock isotopic equilibrium is suggested, as the apatite - whole rock $(^{87}Sr/^{86}Sr)_i$ ratios are equivalent within analytical

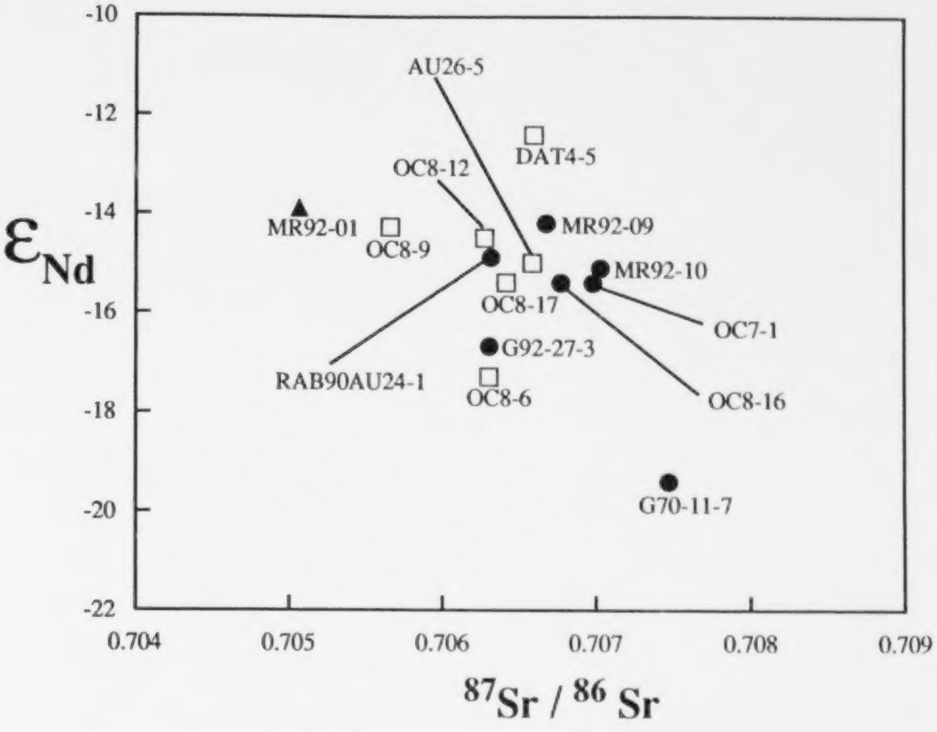


FIGURE 4.1 ε_{Nd} versus $^{87}Sr/^{86}Sr$ covariation diagram for the Milk River data (labeled by sample number). Minettes (filled circles); mica-clinopyroxenites (open squares); diorite porphyry (filled triangle). Note: The mica-clinopyroxenites from Coulee 29 form a field that overlaps with that of the Milk River minettes. Samples are as follows; *olivine minette* (OC7-1, OC8-16, MR92-10, G92-27-3, RAB90AU24-1), *minette* (MR92-09), *felsic minette* (G70-11-7). Note: OC7-1 and OC8-16 are from Coulee 29.

error (0.70631±6 vs. 0.70629±2). However, phlogopite and diopside separates show differences in initial ratios that are larger than analytical error. For sample OC8-9 (mica-clinopyroxenite) apatite - whole rock and diopside - whole rock $(^{87}Sr/^{86}Sr)_i$ ratios are within analytical error (0.70568±1 and 0.70577±2, respectively vs. 0.70566±10). Phlogopite - whole rock and diopside whole rock from minette sample OC7-1 show differences in initial ratios that are slightly larger than analytical error (0.70655±2 and 0.70654±3, respectively vs. 0.70698±6).

The source region for the Milk River rocks is characterized by unradiogenic initial $^{143}Nd/^{144}Nd$ compositions which range from 0.51194 to 0.51158 (ε_{Nd}= -12.4 to -19.3) (Fig. 4.1 and 4.3). The $^{143}Nd/^{144}Nd$ values for mineral concentrates from the mica-

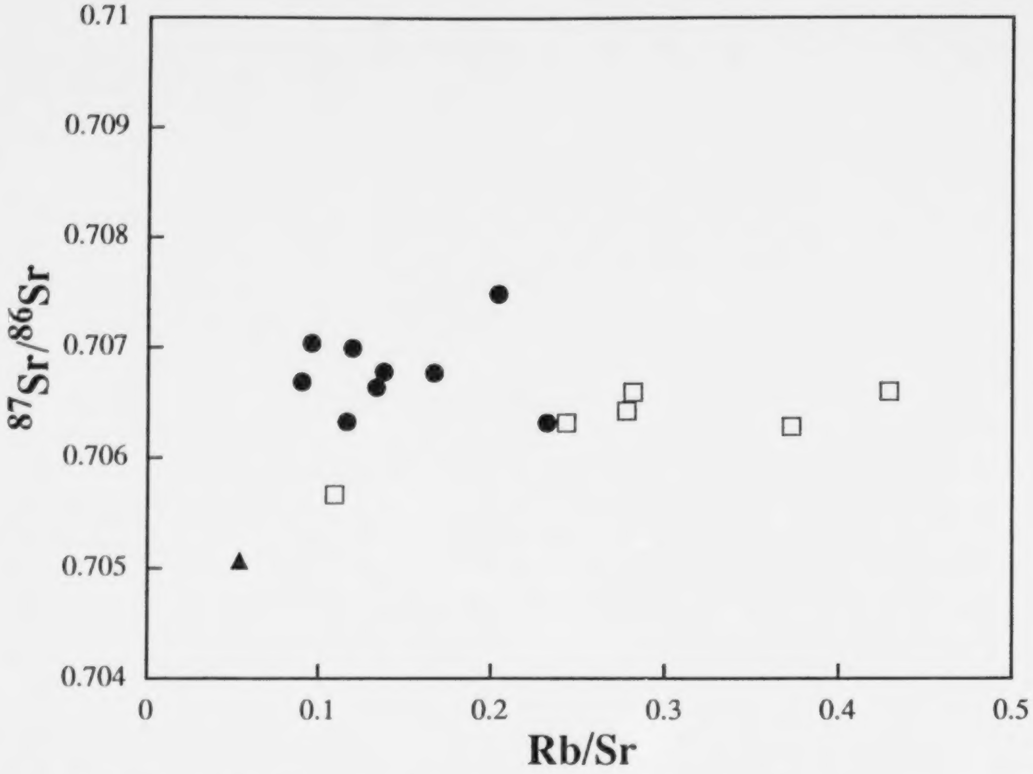


FIGURE 4.2 $^{87}Sr/^{86}Sr$ versus Rb/Sr diagram for the Milk River samples. The data shows a wide range in Rb/Sr but a relatively narrow range in $^{87}Sr/^{86}Sr$. Minettes (closed circles); mica-clinopyroxenites (open squares); diorite porphyry (closed triangle).

clinopyroxenites (OC8-6, OC8-9 and AU26-5) and the minette dike OC7-1 lie within this (0.51186 - 0.51167) whole rock range (see Appendix D). For the mica-clinopyroxenites Nd, model ages with respect to CHUR range from 1410 Ma to 3180 Ma and from 1250 to 1840 Ma for the minettes.

The Pb isotopic compositions of the Milk River samples are within the range $^{206}Pb/^{204}Pb$ of 16.958 to 17.687, $^{207}Pb/^{204}Pb$ of 15.285 to 15.499 and $^{208}Pb/^{204}Pb$ of 36.958 to 37.791.

Sr-Nd Isotope Systematics

Mafic alkalic rocks formed in continental settings display a "fan" of possibilities between two endmember trends in ε_{Nd} vs. $^{87}Sr/^{86}Sr$ space (Fig. 4.3). One endmember is a low-angle trend to radiogenic $^{87}Sr/^{86}Sr$ and is characterized by rocks plotting close to bulk earth values, to leucitites of the central Italian volcanics and lamproites from western Australia and southeast Spain. The other endmember is a subvertical trend to unradiogenic Nd at relatively constant $^{87}Sr/^{86}Sr$ and includes the lamproites of Smoky Butte and the Leucite Hills and the sodic alkalic intrusives of the Crazy Mountains in south central Montana. Rocks plotting near bulk earth isotopic compositions include the monticellite peridotites from the Missouri Breaks and Haystack Butte. Minettes, mafic phonolites, shonkinites and latites from the Highwood and Bearpaw Mountains have ε_{Nd} values that span nearly the entire range from the most radiogenic Leucite Hills samples to the most radiogenic Smoky Butte samples (Fig. 4.3). The Highwood and Bearpaw Mountains rocks , however, contain Sr that is more radiogenic than other centers in the Wyoming Province. The Milk River samples have ε_{Nd} values spanning a similar range as the rocks from the Highwood Mountains, but are characterized by less radiogenic Sr than the Highwood and Bearpaw Mountains rocks. It is important to note that small but systematic differences between inclusions and between dikes define overlapping fields in (Fig. 4.1). This relationship suggests that the inclusions are of cognate origin.

The Milk River samples show no correlation between isotopic composition and any fractionation index (e.g., MgO and Ni), consistent with these magmas not being subjected to major crustal contamination effects. This suite of samples shows a wide range in Rb/Sr and a restricted range in initial Sr (Fig. 4.2). Fig. 4.4 shows that there is no correlation between Rb/Sr and Ni (as a fractionation index), implying that neither crystal fractionation nor varying degrees of partial fusion was responsible for the variations in Rb/Sr. This suggests that the Rb/Sr heterogeneity was inherited from the source region, and the lack of correlation between $^{87}Sr/^{86}Sr$ and Rb/Sr further implies the presence of a young component. This feature is observed in other suites. O'Brien *et al.*, (1991) draws the same conclusion for the mafic to felsic potassic magmatic rocks of the Highwood Mountains, Montana and Van Kooten (1981) also reached the same conclusion for the ultrapotassic basalts from the Sierra Nevada of California; rocks from both centers also show a lack of correlation between $^{87}Sr/^{86}Sr$ and Rb/Sr.

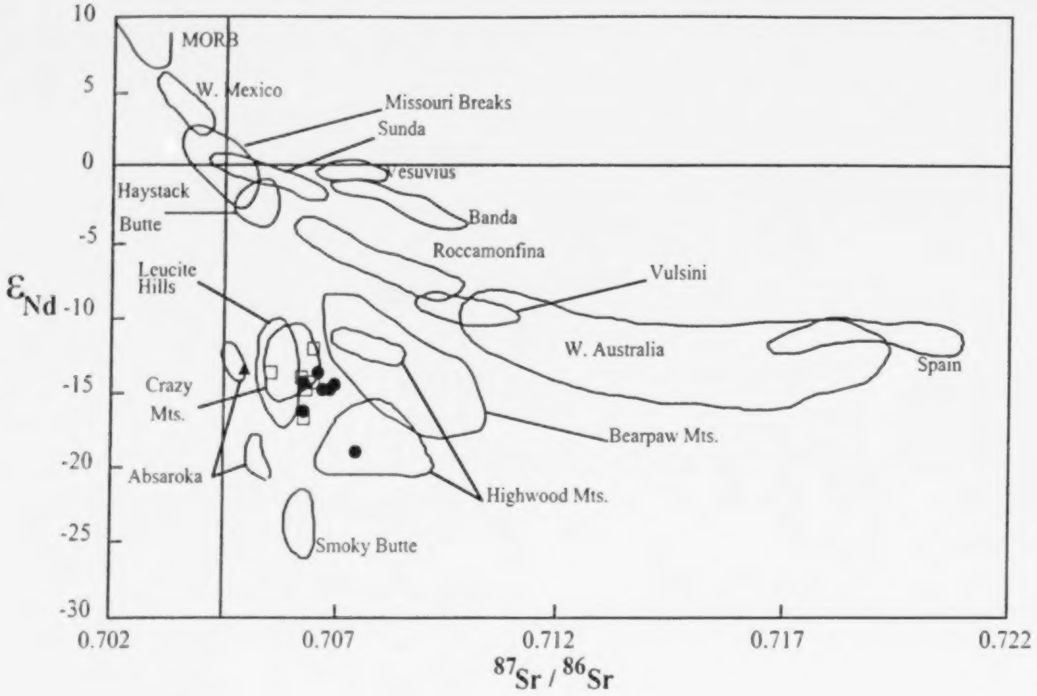


FIGURE 4.3 Sr and Nd compositions for alkalic magmatic rocks from the Milk River area of southern Alberta and elsewhere. Mica-clinopyroxenite inclusions from Coulee 29 (open squares); minette dikes (closed circles); diorite porphyry (closed triangle). See O'Brien *et al.*, 1991 for data sources. Note: The mica-clinopyroxenite inclusions, from Coulee 29, form a field that overlaps that of the Milk River minettes.

Pb-Pb Isotope Systematics

The isotopic compositions of the Milk River minettes as well as the mica-clinopyroxenites from Coulee 29 define overlapping fields in $^{207}Pb/^{206}Pb$ and $^{208}Pb/^{206}Pb$ space (Fig. 4.5 and Fig. 4.6) as is also apparent in the ε_{Nd} - Sr diagram.

A similar dichotomous relationship between the Wyoming Province and the central Italian volcanics and Spanish lamproites as observed in ε_{Nd} vs. $^{87}Sr/^{86}Sr$ space is also evident in Pb-Pb space (Fig. 4.5 and Fig. 4.6). The Wyoming province mafic alkalic rocks contain a non-radiogenic Pb component that developed in an old U and Th depleted

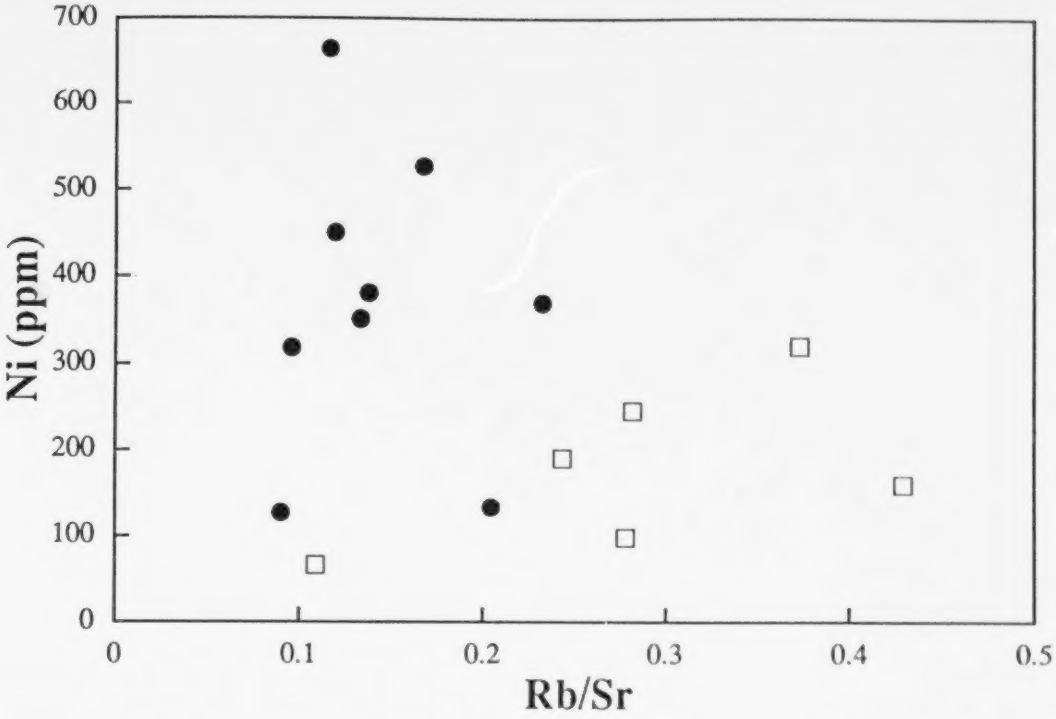


FIGURE 4.4 Ni versus Rb/Sr plot for the Milk River samples. Minettes (closed circles); mica-clinopyroxenites (open squares). For the minettes it is important to note that the samples with higher Ni contents overlap in Rb/Sr with samples with less Ni content.

source. The Milk River rocks as with the rest of the rocks from the Montana - Wyoming alkalic province plot to the left of the geochron indicating a major non-radiogenic Pb component that developed in an old U and Th depleted source. Fraser *et al.*, (1985) argues against an old Pb enrichment event based on the low Pb concentrations in the Smoky Butte lamproites. Overall, the Wyoming Province Pb-Pb array appears to be a mixing line between nonradiogenic Pb and average crustal Pb. The Highwood Mountains rocks, however, define an array that may be interpreted as a secondary isochron giving an age of 1870±250 Ma, the more sodic Crazy Mountains rocks are more scattered and give an "age" of 1400±1600 Ma, whereas the Smoky Butte lamproites give an isochron age of 2100±600 Ma (O'Brien, 1991). The Milk River minettes define an extremely poorly constrained secondary isochron from which no age information can be gleaned. Nevertheless, the sources of the Milk River , Highwood Mountains and Smoky Butte differ with respect to $^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ compositions. The difference between the Highwood

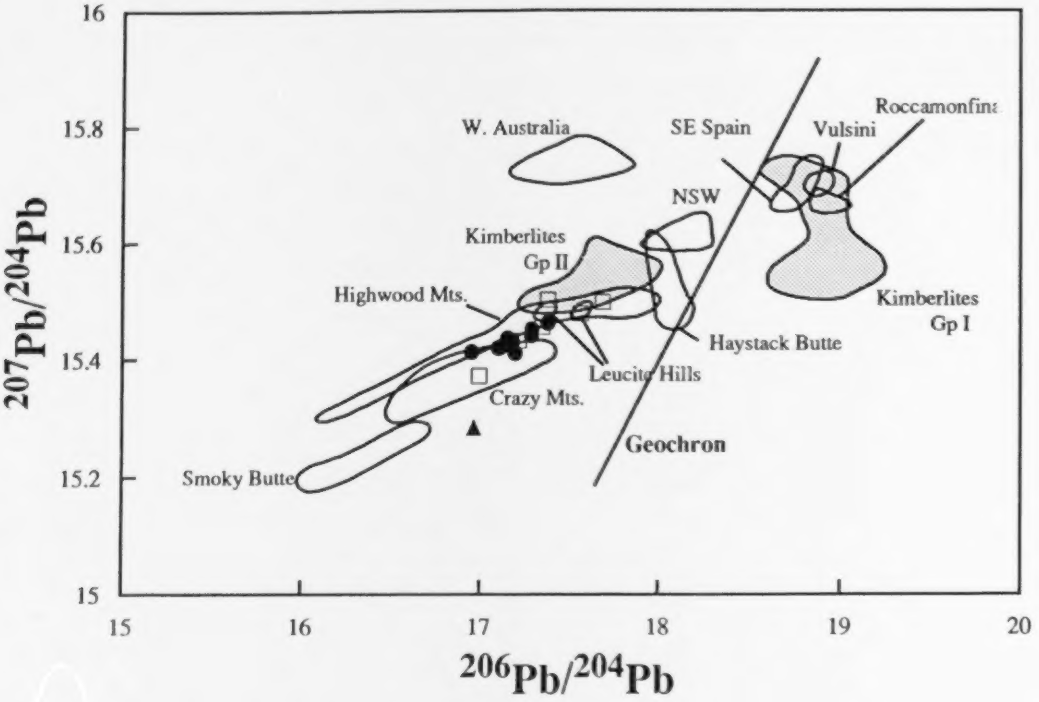


FIGURE 4.5 $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ diagram for alkalic magmatic rocks from the Milk River area and elsewhere. See O'Brien *et al.*, 1991 for data sources. Minettes (closed circles); mica-clinopyroxenites (open squares); diorite porphyry (closed triangle). Note that the minettes form a field that overlaps that of the mica-clinopyroxenites as is also apparent in ε_{Nd} versus $^{87}Sr/^{86}Sr$ space.

Mountains and Milk River trend is better defined in $^{208}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ space (Fig. 4.6).

GEOCHRONOLGY

A Rb-Sr mineral isochron for a mica-clinopyroxenite nodule from Coulee 29 (apatite, clinopyroxene, whole-rock and three magnetic fractions of acid leached phlogopite) yields an age of 49.0±0.8 Ma (Fig. 4.7a). A slightly older age, 51.9±1.7 Ma, is indicated by a Rb-Sr mineral isochron for another mica-clinopyroxenite nodule (apatite, clinopyroxene, whole-rock and three magnetic fractions of acid leached phlogopite) from

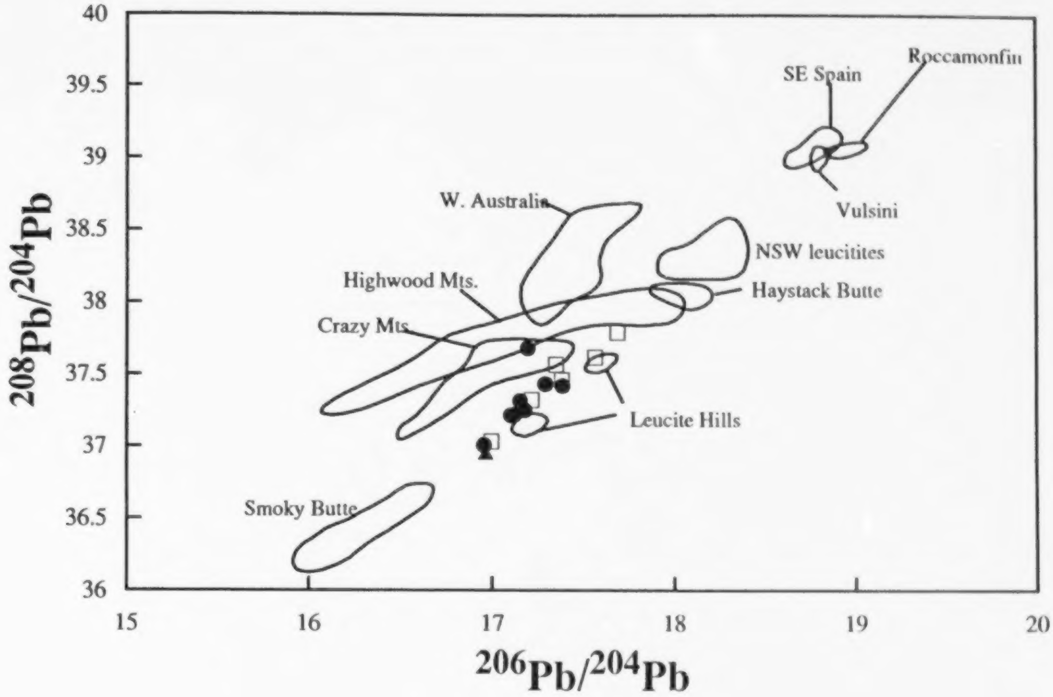
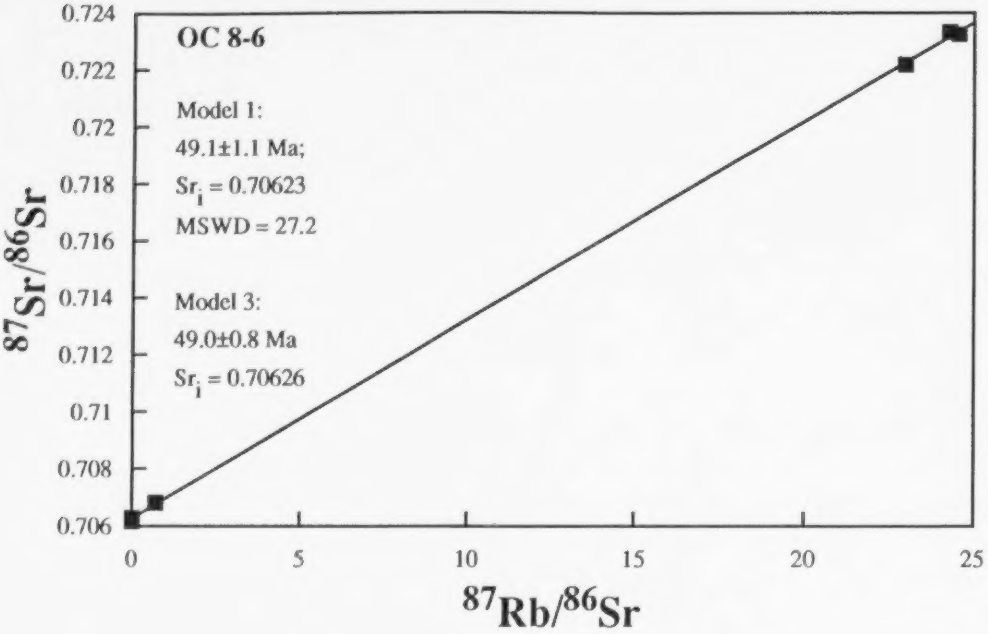


FIGURE 4.6 $^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ diagram for alkalic magmatic rocks from the Milk River area and elsewhere. See O'Brien *et al.*, 1991 for data sources. Minettes (closed circles); mica-clinopyroxenites (open squares); diorite porphyry (closed triangle). Note that the minettes form a field that overlaps that of the mica-clinopyroxenites as is also apparent in ε_{Nd} versus $^{87}Sr/^{86}Sr$ space.

Coulee 29 (Fig. 4.7b). An associated minette dike, from Coulee 29, yields a Rb-Sr model age (clinopyroxene and phlogopite) of 50±0.3 Ma.

The mica-clinopyroxenite inclusions and the minette dike, from Coulee 29, are middle Eocene in age. The calculated ages for the inclusions and minette dike do overlap, consistent with a cognate origin of the inclusions. Both mineral isochrons for the nodules are essentially two-point fits between Rb-rich phlogopite fractions and a clinopyroxene, apatite and whole-rock cluster with low Rb. Slight variations in Rb/Sr of the phlogopite, caused by the combined effects of weathering, alteration and possibly acid leaching may significantly affect the calculated ages, with the result that calculated uncertainties (York, 1969) may therefore be too low. Neither mineral isochron has mean square weighted deviations near one, indicating that factors other than analytical uncertainty contribute to the scatter of data. In Fig. 4.7 model 1 ages assume variations are a function of analytical



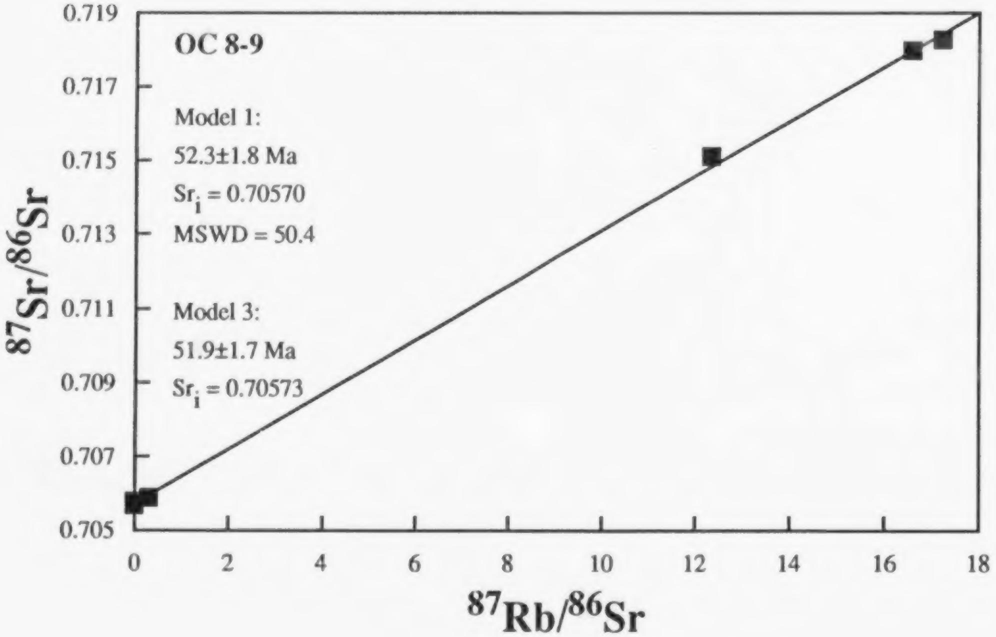


FIGURE 4.7 Rb-Sr mineral isochrons (apatite, clinopyroxene, whole-rock and three magnetic fractions of acid leached phlogopite) for two mica-clinopyroxenite nodules from Coulee 29, Milk River area southern Alberta.

uncertainty and are valid only for MSWD near one, model 3 ages however, assume scatter of data to be a function of both analytical uncertainty and a variation in initial isotopic ratios.

Published ages for rocks from the Sweetgrass Hills igneous complex range from 49 to 53 Ma (Baadsgaard *et al.*, 1961, Kjarsgaard and Davis, 1994; Marvin *et al.*, 1980). The 49.1 to 52.3 Rb-Sr ages of the mica-clinopyroxenites, and the 50 Ma Rb-Sr model age for the minette dike, from Coulee 29, are in excellent agreement with previous K-Ar and Rb-Sr age determinations from the area.

CONCLUSIONS

1) Initial Sr and Nd isotopic ratios for mineral separates are generally in agreement with those for the bulk rocks, suggesting that there was no significant disturbance of these isotopic systems.

2) The mica-clinopyroxenite inclusions from Coulee 29 and the Milk River minettes cannot be differentiated in terms of isotopic compositions. Small but systematic differences between the dikes and between the inclusions define overlapping fields in ε_{Nd} - $^{87}Sr/^{86}Sr$ and $^{208}Pb/^{206}Pb$, $^{207}Pb/^{206}Pb$ space. This argues for a cognate origin of the mica-clinopyroxenite inclusions whereby they crystallized from the minette magmas at depth.

3) Calculated Rb-Sr ages for 2 mica-clinopyroxenite inclusions and a minette dike, from Coulee 29, are in agreement with previous age determinations, by others, for rocks from the Sweetgrass Hills igneous complex.

4) The isotopic compositions of the Milk River magmas occupy similar portions in ε_{Nd} - $^{87}Sr/^{86}Sr$ and $^{208}Pb/^{206}Pb$, $^{207}Pb/^{206}Pb$ space as other Wyoming Province samples.

Chapter 5

Petrogenesis

INTRODUCTION

Minettes of Eocene age occur at several centers within the Montana alkalic province (O'Brien *et al.*, 1991; Macdonald *et al.*, 1992). The Sweetgrass Hills, Highwood Mountains, and Bearpaw Mountains all contain minettes with a very similar petrogenetic history.

In this chapter, the whole-rock compositions of the Milk River minettes of the Sweetgrass Hills Igneous Complex are reviewed; the role of fractional crystallization and magma mixing in the evolution of the Milk River minettes are discussed. Isotopic compositions and trace element abundances are utilized to develop a petrogenetic model of the Milk River minette magmas, which is consistent with the current knowledge of Eocene tectonics and contemporaneous magmatism of the region. The similarities and differences among the Eocene minettes from the Sweetgrass Hills, Highwood Mountains and Bearpaw Mountains are also examined.

PARENTAL LIQUIDS

The primitive *olivine minettes* satisfy commonly accepted criteria for primary melts. The high Mg#, Mg, Ni and Cr contents, (Mg# >70, 11-14 wt.% MgO, Ni 450-664 ppm, Cr 750-960 ppm) are consistent with an origin in equilibrium with mantle peridotite (Sato, 1977; Frey *et al.*, 1978; Clague and Frey, 1982). The derivation of minettes from the mantle is supported by the presence of populations of mantle-derived ultramafic xenoliths (e.g., Ehrenburg, 1982; Macdonald *et al.*, 1992; Carlson and Irving, 1994), as well as experimental studies (Ruddock and Hamilton, 1978; Esperanca and Holloway, 1987). It is possible, however, that some of the Milk River minettes have been modified by accumulation of crystals.

Two features suggest that the *olivine minettes* approximate liquid compositions. In volcanic rocks in which accumulation has occurred, phenocrystal abundance should correlate with certain compositional parameters (Wallace and Carmichael, 1989). For example, accumulation of olivine should result in positive correlations with bulk rock concentrations of Ni, Cr and MgO and negative correlations with FeO, Al_2O_3 and SiO_2. The Milk River minettes show no simple correlation between phenocryst abundance and bulk rock MgO or other compositional parameters. The overall relationship between the phenocryst assemblages and bulk rock compositions, described earlier, is similar to experimentally determined crystal-liquid relationships in an Arizonan minette (Esperanca and Holloway, 1987). On the other hand, Ni concentrations provide evidence of possible olivine and clinopyroxene accumulation. Ni abundances of primary mantle derived magmas are believed to be in the range 235-400 ppm (Sato, 1977; Frey *et al.*, 1978), whereas some of Milk River minettes have >900 ppm Ni. The porphyritic nature of the Milk River minettes is consistent with some degree of accumulation or crystallization.

Petrographic evidence described in Chapter 2 is consistent with partly mixed phenocryst populations in the minettes, some being possibly derived from the mixing of minette magmas of differing degrees of evolution. Macdonald *et al.* (1992) demonstrated this complication for the Bearpaw minettes using phase relationships in the model system forsterite - kalsilite - silica. Shown in Fig. 5.1 are the compositions of the minettes from Milk River area, Highwood Mountains, and Bearpaw Mountains plotted in terms of their normative Mg_2SiO_4 - $CaMgSi_2O_6$ - $KAlSiO_4$ - SiO_2 components. With increasing pressure and a_{H_2O}, the phase volume of phlogopite expands relative to those of the other phases. Even at 20 kb pressure (Fig. 5.1), the compositions of the phlogopite-bearing minettes from the Highwood and Bearpaw Mountains as well as most of the Milk River minettes lie within the forsterite phase volume. This indicates that either the phlogopite phase volume in the natural systems was greater relative to those in the synthetic system, or the phlogopite phenocrysts in the minettes were derived by magma mixing (Macdonald *et al.*, 1992).

A compromise between various lines of evidence as suggested by Macdonald *et al.* (1992) for the Bearpaw magmas may also be applied to the Milk River magmas. Crystallization of the Milk River compositions would first involve olivine and clinopyroxene, then olivine reacted to phlogopite as the olivine/phlogopite reaction boundary curve is reached. The range of magmas thus formed was subjected to varying degrees of olivine and clinopyroxene accumulation, and to variable degrees of mixing between magmas containing higher and lower temperature assemblages.

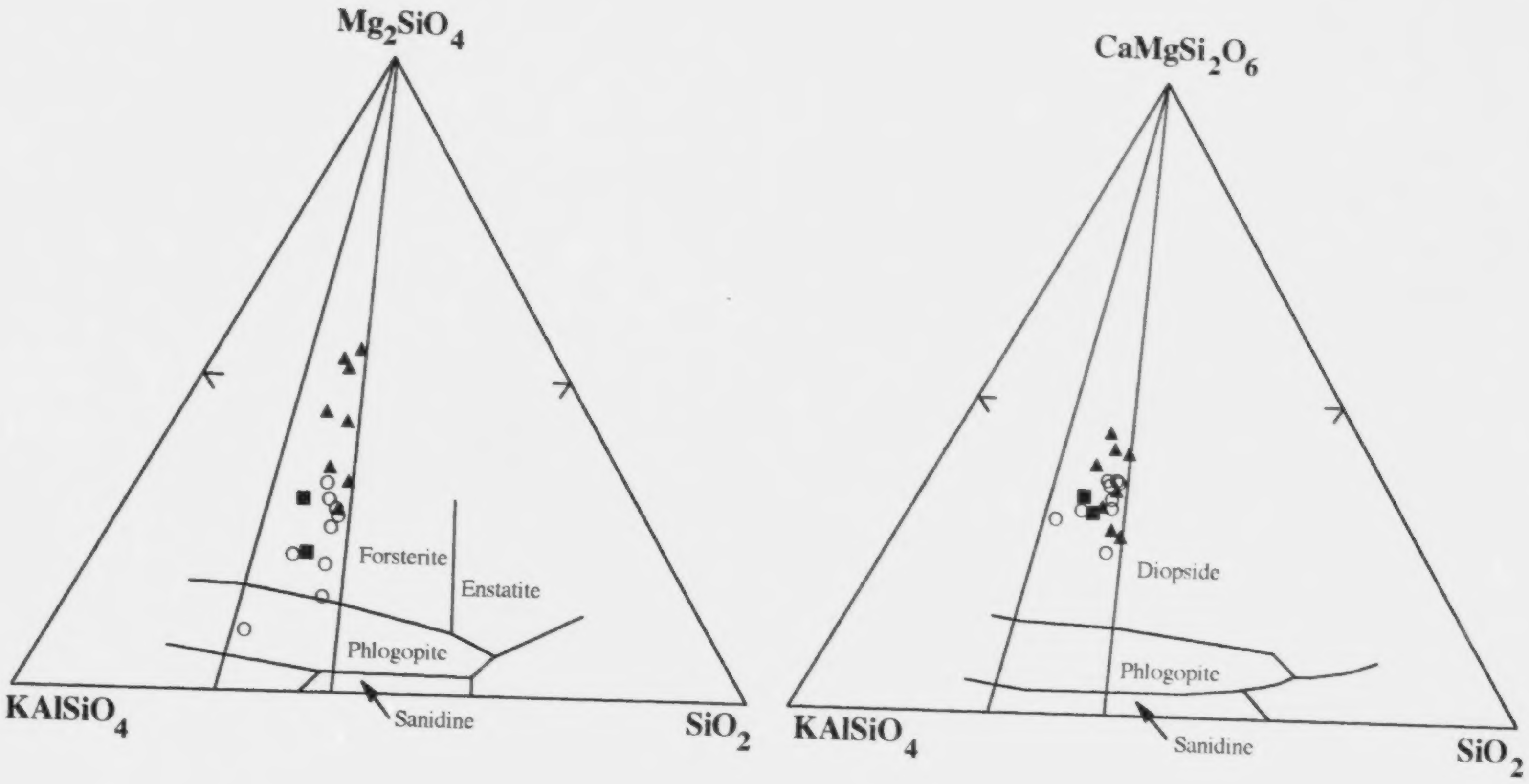


FIGURE 5.1 Normative forsterite-diopside-kalsilite-silica (wt.%) diagrams for the Milk River minettes, open circles; Highwood minettes (O'Brien et al., 1991), closed squares; Bearpaw minettes (Macdonald et al., 1992), closed triangles. Approximate phase relationships from Wallace and Carmichael (1989) from water-saturated and -undersaturated experiments at pressures between 4 and 20 Kb.

The presence of minettes with phenocrysts of olivine, clinopyroxene and phlogopite may imply that the primary magma lay close to a natural olivine/clinopyroxene - phlogopite reaction point. To understand better the compositions of liquids in equilibrium with olivine, clinopyroxene and phlogopite, the compositions of the Milk River minettes have been projected from kalsilite into the forsterite-diopside-sanidine plane, and from diopside onto the forsterite-kalsilite-silica plane. Fig. 5.2 and Fig. 5.3 show these projections, and relationships proposed by Esperanca and Holloway (1987; and Wallace and Carmichael, 1989). Liquids in equilibrium with olivine, clinopyroxene and phlogopite become more MgO rich and K-Al poor with increasing pressure as the phlogopite phase volume expands. Comparison of the minette compositions with the experimental phase relations show that the primary Milk River minettes could have been generated at pressures greater than 17 kb from a mantle source containing olivine, clinopyroxene and phlogopite.

The compositions of the *olivine minettes* in the Milk River area (Fig. 5.2) may be consistent with derivation by partial melting of olivine, clinopyroxene and phlogopite bearing mantle (phlogopite-peridotite) at >17 kb. Macdonald *et al.* (1992) reached a similar conclusion for the primary magmas in the Bearpaw Mountains. Preliminary studies by Hearn *et al.* (1988, 1989) of an extensive ultramafic xenolith suite in minettes from the Bearpaws may constrain possible source regions for the Bearpaw minettes (Macdonald *et al.*, 1992). The xenolith suite includes deformed peridotites comprised dominantly of Cr-spinel dunites and harzburgites that have sheared textures, and contain olivine (Fo88-92), Cr-diopside, enstatite, Cr-spinel, and phlogopite. The existence of phlogopite in sheared, otherwise refractory peridotites is suggestive that the mantle experienced a melt extraction event followed by metasomatic enrichment by K-bearing fluids or melts (Macdonald *et al.*, 1992). In a detailed Os, Sr, Nd and Pb isotopic study of ultramafic xenoliths from the northwestern Wyoming craton, Carlson and Irving (1994) describe a suite of spinel peridotite, pyroxenite and glimmerite xenoliths in Eocene minette dikes from the Highwood Mountains and Eagle Buttes, Montana. These xenoliths also reveal a prolonged, yet episodic, history of melt removal and re-fertilization within the shallow lithosphere mantle of the Archean Wyoming Craton. These workers also suggest the importance of phlogopite veined materials like the Highwood websterite and glimmerite in the origin of these magmas. This is consistent with models of K-rich magmas that emphasize the importance of veins in the mantle (Foley, 1992).

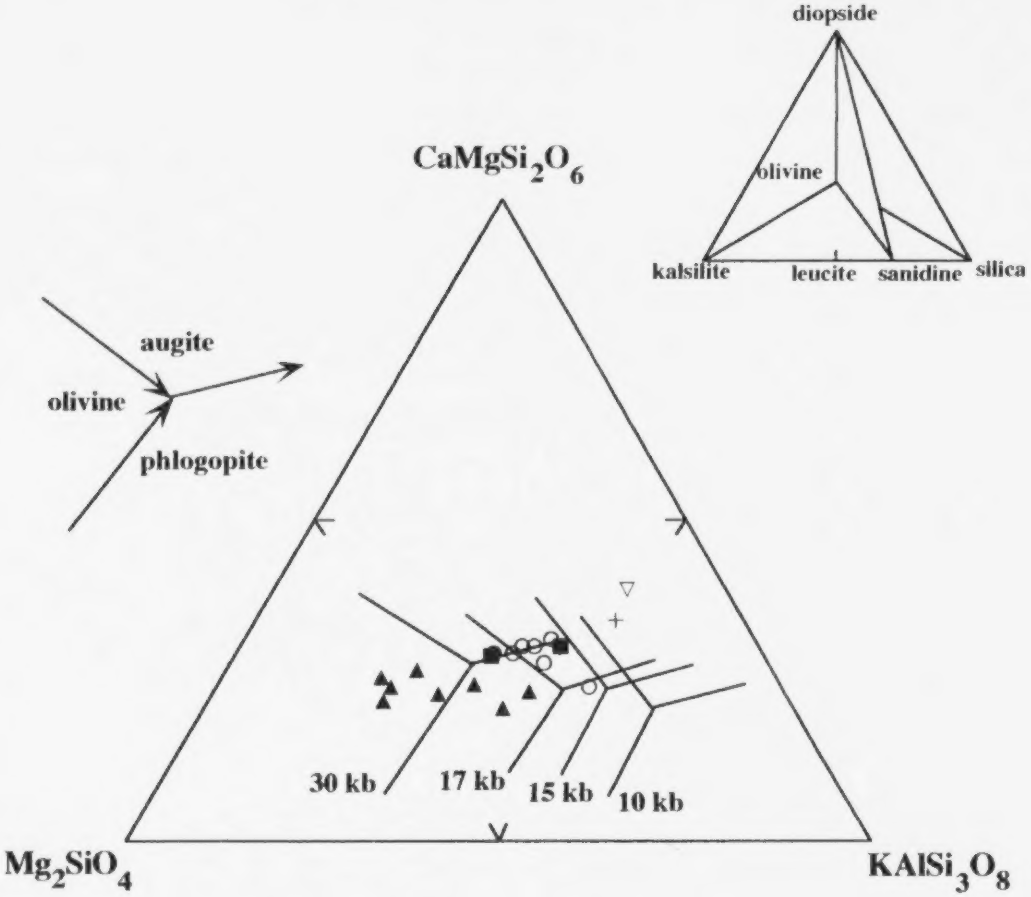


FIGURE 5.2 Compositions of Milk River minettes open circles (olivine minettes), cross (minette), open triangle (felsic minette); Highwood minettes (O'Brien *et al.*, 1991), closed squares; Bearpaw minettes (Macdonald *et al.*, 1992), closed triangles, projected from kalsilite into the augite-olivine-sanidine pseudoternary system (mole%). Phase boundaries constructed by Wallace and Carmichael (1989) from experimental results of Esperanca and Holloway (1987). Phase boundaries for 30 Kb are extrapolated from lower pressure data. Molecular norms calculated using Fe^{2+} = 0.85 total Fe following Macdonald *et al.* (1992).

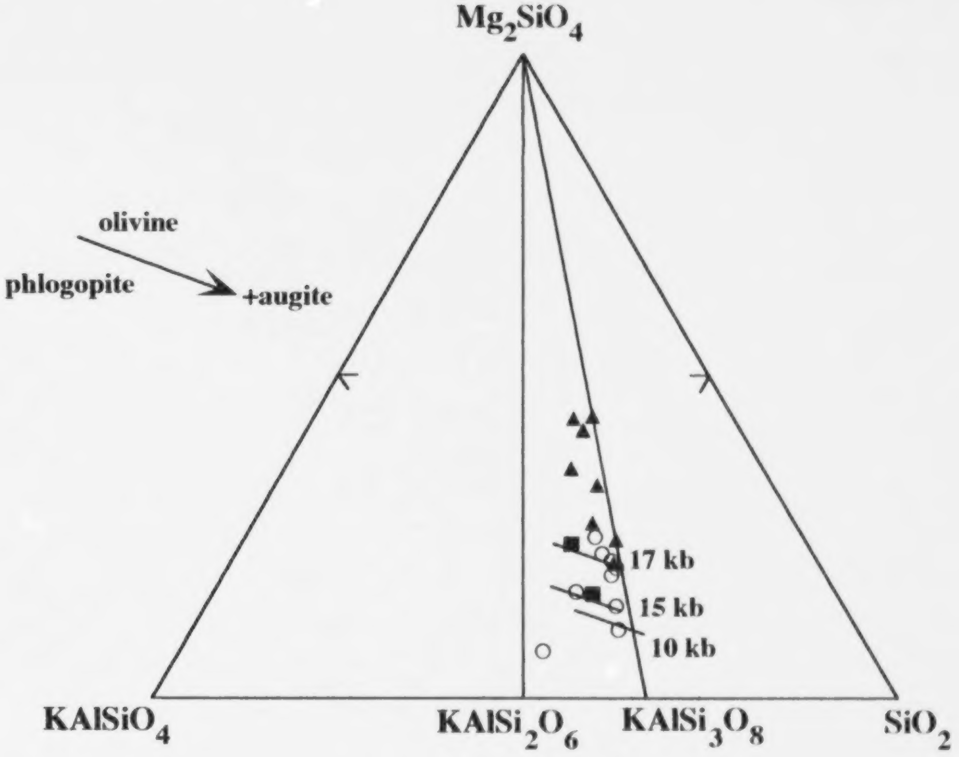


FIGURE 5.3 Augite saturated olivine-kalsilte-silica diagram computed by same method as Fig. 5.2 (Wallace and Carmichael, 1989). Milk River minettes open circles; Highwood minettes (O'Brien *et al.*, 1991), closed squares; Bearpaw minettes (Macdonald *et al.*, 1992), closed triangles.

CHARACTERIZATION OF SOURCE REGIONS

Minettes

Differences between samples of the Milk River minettes in incompatible trace element and isotopic ratios indicate that the parental magmas were derived from a heterogeneous source or sources. In this section, the possibility that the minettes have acquired their isotopic and chemical character from separate mantle sources is investigated.

The mantle-normalized abundance patterns of incompatible elements in the minettes and mica-clinopyroxenites are shown in Fig. 5.4. Several features are noteworthy in these diagrams. All samples are enriched in Ba relative to Rb and show strong negative Th and

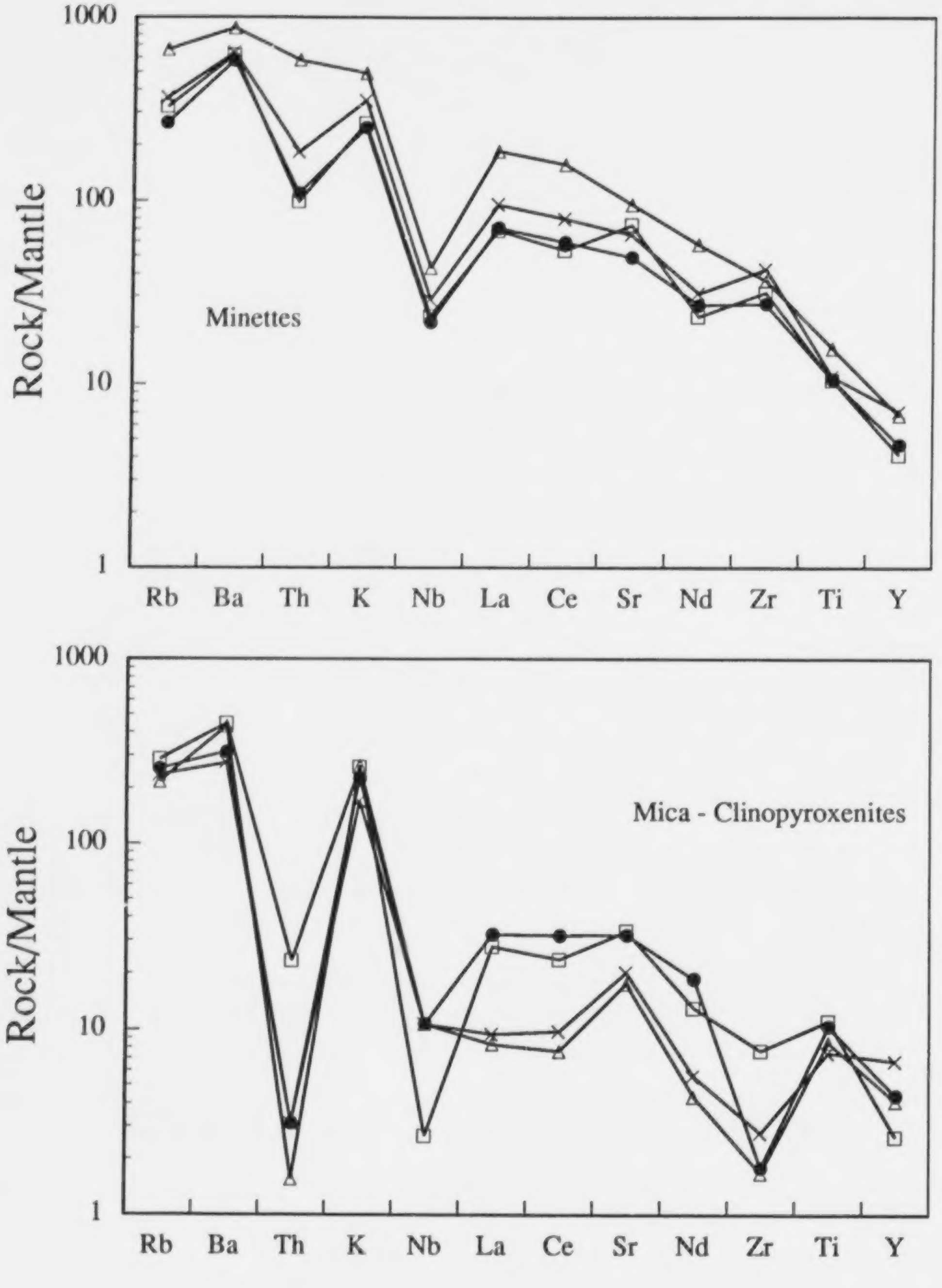


FIGURE 5.4 Mantle-normalized element spider plots for representative Milk River minettes and mica-clinopyroxenites. Normalizing values are from Taylor and McLennan (1985).

Nb anomalies, relative to La. These patterns as well as the isotopic characteristics of the Milk River minettes cannot have been derived from mantle sources geochemically similar to an ocean island basalt or a mid ocean ridge basalt source without the addition of one or more separate components.

The Milk River minettes have trace element and isotopic characteristics that are explicable by a three component source model, as has been suggested for other rocks of the Wyoming province by Irving *et al.* (1988), Macdonald *et al.* (1992), O'Brien *et al.* (1991) and Scambos and Farmer (1988). One such component is LREE enriched, HFSE depleted with low $^{143}Nd/^{144}Nd$ ratios, and is most likely an ancient lithospheric mantle source, possibly represented by phlogopite bearing peridotite xenoliths in the Bearpaw as well as the Highwood minettes described by others. A second end-member, asthenospheric mantle, has low $^{87}Sr/^{86}Sr$, ε_{Nd} and is recognizable as the dominant component in the essentially coeval kimberlitic rocks of the Missouri Breaks as well as the monticellite peridotite/alnoite diatremes of Haystack Butte. The third component is characterized by high $^{87}Sr/^{86}Sr$, Rb/Sr, and Sm/Nd within the minettes. This component also shows a lack of correlation between $^{87}Sr/^{86}Sr$ and Rb/Sr, consistent with a young age. O'Brien *et al.* (1991) have interpreted these characteristics as well as Ba enrichments and Nb and Ti depletions as indicative of an Eocene to late Cretaceous subduction component in minettes to the Highwood Mountains. Macdonald *et al.* (1992), on the other hand, feel that the evidence for a subduction component is equivocal in the Bearpaw Rocks. These workers state that the high Sr/Nd characteristics of arc magmas is absent in the Bearpaws and that the high Rb/Sr ratios of minettes are uncommon in subduction zones. They believe that negative Ti and Nb anomalies are often related to the presence of a residual phase (amphibole, Ti-rich mica, or titanite) in the mantle sources. Macdonald *et al.* (1992), therefore, suggest that there is no reason why such a phase should be limited to subduction zones only and they believe that the enrichment mechanism for this third component remains unknown.

Xenoliths

Elemental and isotopic studies of spinel peridotite, pyroxenite and glimmerite xenoliths in Eocene minette dikes (Carlson and Irving, 1994) suggest that the shallow lithosphere mantle of the Archean Wyoming Craton experienced a number of episodes of depletion and possibly enrichments in major and trace elements during the Archean (Wooden and Mueller, 1988; Aleinikoff *et al.*, 1989) and mid-Proterozoic. Carlson and Irving (1994) suggest that ancient, but highly variable, enrichment in incompatible elements is indicated by extreme Sr, Nd and Pb isotopic compositions within the xenoliths. They also found Re depletion model ages (T_{RD}) of 2.7 to 2.9 Ga in some of the peridotites and they interpret this to reflect melt removal during the Archean. The majority of the xenoliths, however, define Pb-Pb and Sm-Nd isochrons of mid-Proterozoic age and have Re-Os T_{RD} ages of 2 Ga or less (Carlson and Irving, 1994). This mid-Proterozoic age is interpreted to reflect either the time of formation of these peridotites or a time of severe overprinting of the incompatible element budget of pre-existing material by interaction with migrating fluids and/or melts (Carlson and Irving, 1994).

The Milk River minettes show Nd model ages relative to CHUR ranging from 1.3 Ga to 1.8 Ga and Nd model ages relative to depleted mantle for the Highwood primitive samples range from 1.5 Ga to 2.2 Ga (O'Brien *et al.*, 1991). O'Brien *et al.* (1991) also reported a 1.9 Ga Pb-Pb secondary isochron age for the Highwood Mountains rocks. Depleted mantle (T_{DM}) model ages for Bearpaw minettes and latites range from 1.5 Ga to 2.2 Ga but appear to be dominated by a 2.1 - 2.2 Ga population (Macdonald *et al.*, 1992). Data presented by Dudas *et al.* (1987) for alkalic and subalkalic sources for rocks from the Crazy Mountains suggest a mantle enrichment event at (T_{DM}) 1.5 - 1.8 Ga. It is significant that these time periods overlap with major thermotectonic events in the evolution of the North American craton (cf. Hoffman, 1988, 1989). These ages may reflect subduction related magmatism/events and metasomatic activity during assembly of early Proterozoic orogens with the Wyoming-Rae-Hearne and Slave cratons in western North America (Hoffman, 1988, 1989; Bickford *et al.*, 1990; Collerson *et al.*, 1990). The exact nature of the mid-Proterozoic event is not well defined but it may represent a time of extensive melt infiltration beneath central Montana associated with creation of the Great Falls tectonic zone (Carlson and Irving, 1994).

Isotopic and trace element compositions of the Milk River minettes, therefore, is consistent with contributions from three mantle components. It is speculated that the minettes were generated in a similar fashion as the model proposed by O'Brien, (1991) for Highwood primary olivine minettes. The preferred tectonomagmatic model involves partial melting of the asthenospheric mantle wedge above a low angle subducted slab, or perhaps within an extensional regime. As the magmas ascended they underwent assimilative interaction with the lithosphere that had been enriched and depleted during several events, some of which may have been related to subduction. The assimilative interaction with ancient, geochemically extreme, phlogopite bearing metasome veined Wyoming Craton mantle keel was sufficiently low that the lithospheric signature was not homogenized, resulting in isotopic and trace element heterogeneity.

FRACTIONAL CRYSTALLIZATION

The phase relationships in the system forsterite-diopside-sanidine (Fig. 5.2 and Fig. 5.3), may suggest that the *minette* and *felsic minette* could have formed either by partial melting at lower pressures than did the olivine minettes or by fractional crystallization of olivine, clinopyroxene and phlogopite from *olivine minette* magmas generated at higher pressures. The geochemistry of the minettes, presented on variation diagrams of major and trace elements in Chapter 3, is more consistent with the latter. An attempt to model quantitatively the crystal fractionation history of the Milk River minettes has been made. An accurate attempt at modeling would require the identification of likely parent-daughter melt pairs and of the fractionating phenocryst phases and more precise control on partition coefficients appropriate for hydrous alkalic magmas. For the minettes from the Milk River area the possibility of crystal accumulation and magma mixing processes has resulted in complex phenocryst/xenocryst assemblages. The same processes have also been noted to result in scatter of whole rock/trace element arrays for rocks from the Highwoods (O'Brien *et al.*, 1988a) as well as the Bearpaw data (Macdonald *et al.*, 1992).

To test if the Milk River whole rock compositional trends could represent fractional crystallization paths, two samples were chosen for fractionation modeling: the most primitive *olivine minette* (RAB90-Au24-1), and a slightly more evolved *olivine minette* (MR92-10).

Least squares mixing calculations (using the program Mix n' Mac developed by D.R. Mason, Amdel, Adelaide) are used to model a major element fractionation trend between RAB90-Au24-1 and MR92-10 to test the plausibility of fractional crystallization. Phases removed were restricted to those occurring in the mica-clinopyroxenite nodules carried by the minettes (mineral compositions are listed in Table 5.1). The average compositions for diopside, phlogopite and apatite from the mica-clinopyroxenites nodules, were used.

TABLE 5.1

Analyses of minerals used in Least-squares Calculation

Mineral Compositions extracted from RAB90-Au24-1			
	Diopside	*Phlogopite*	*Apatite*
SiO_2	53.77	38.92	0.12
TiO_2	0.23	1.91	0.00
Al_2O_3	0.92	13.32	0.00
FeO	5.24	9.08	0.20
MnO	0.15	0.06	0.04
MgO	16.88	20.92	0.37
CaO	22.56	0.03	53.63
Na_2O	0.36	0.39	0.07
K_2O	0.00	9.95	0.00
P_2O_5	0.00	0.00	40.86

Values represent averaged analysis from mica-clinopyroxenite nodules.

TABLE 5.2

Crystal/liquid D values used in the calculation

	Diopside	*Phlogopite*	*Apatite*
La	0.058	0.020	14.400
Ce	0.100	0.016	24.300
Nd	0.220	0.016	54.300
Sm	0.450	0.016	95.200
Eu	0.480	0.016	102.000
Tb	0.590	0.016	41.400
Yb	0.580	0.020	8.810
Lu	0.530	0.020	3.690

Values from O'Brien (1988), compiled from various sources in the literature and from their own phenocryst/matrix measurements.

To model trace element evolution, the Raleigh fractionation law equation in the form

$$Cl / Co = F^{(D-1)} \qquad \text{where} \qquad D = XKd = Cs / Cl$$

was used (Holm, 1988). In this equation F refers to the fraction of melt remaining, Cl and Co to the concentration of the element in the melt and in the parent melt, respectively, D is the bulk solid-melt partition coefficient, where: Cs is the concentration of the element in the solid, X is the fraction of each of the minerals in the solid phase, and Kd is the partition coefficient for an element in each of the minerals. The D value matrix was taken from O'Brien (1988), which was compiled from various sources in the literature and from their own phenocryst/matrix measurements (see Table 5.2 for values used).

The results of least squares modeling and trace element evolution modeling of the derivation of MR92-10 from RAB90-Au24-1 are presented in Tables 5.3 and 5.4. The calculated and observed minettes have broadly similar major (Σ residuals^2 = 4.73) and trace element compositions. The calculated mica-clinopyroxenite and average mica-clinopyroxenite (Table 5.4) also have broadly similar trace element compositions. The mismatch for some of the elements may be the result of minor fractionation of minerals other than phlogopite, diopside and apatite, and compositional heterogeneities in the rock types used for modeling. The minerals removed from the parent are phlogopite, diopside and apatite in proportions equivalent to those in the average mica-clinopyroxenites found as nodules in the minettes, lending plausibility to this model. Hearne *et al.* (1988) infer

TABLE 5.3

Least-squares calculation of minette fractionation assemblage

Path		***Optimal Assemblage***	***F***
RAB90-Au24-1 to MR92-10		***56% phlog + 42% diop + 2% ap***	***0.51***
	Parent Observed	*Parent Estimated*	*Difference*
SiO_2	45.34	45.50	-0.16
TiO_2	1.02	1.08	-0.06
Al_2O_3	9.22	8.92	0.30
FeO	9.00	7.36	1.64
MnO	0.14	0.12	0.02
MgO	13.63	13.58	0.05
CaO	8.02	8.07	-0.05
Na_2O	1.30	1.07	0.23
K_2O	4.44	5.81	-1.37
P_2O_5	1.02	0.96	0.06
			4.73

Calculated using the program Mix n' Mac developed by D.R. Mason, Amdel, Adelaide.

TABLE 5.4

Results of REE fractionation modeling

Path		***Extracted Assemblage***	***F***
RAB90-Au24-1 to MR92-10		***56% phlog + 42% diop + 2% ap***	***0.51***
	Daughter Observed	*Daughter Calculated*	*Difference (%)*
La	51.80	61.18	15.34
Ce	113.00	115.55	2.21
Nd	49.70	37.82	23.91
Sm	9.52	3.91	58.94
Eu	2.56	0.94	63.31
Tb	0.86	0.60	30.81
Yb	1.49	1.51	1.38
Lu	0.22	0.28	23.00
	Average Nodule Observed	*Cumulate Calculated*	*Difference (%)*
La	19.09	19.80	3.59
Ce	45.86	62.05	26.09
Nd	27.43	44.90	38.91
Sm	5.57	8.22	32.27
Eu	1.44	2.11	31.81
Tb	0.49	0.65	24.75
Yb	0.49	0.65	24.31
Lu	0.07	0.09	13.91

Calculated by spreadsheet method described by Holm, (1988).

crystallization levels in the upper mantle/lower crust for cumulate phlogopite bearing peridotite and pyroxenite xenoliths from the Bearpaw Mountains. It is possible that the mica-clinopyroxenites represent a higher pressure hydrous assemblage (phlogopite + clinopyroxene) that was fractionated from the minettes, possibly in the upper mantle.

CONCLUSIONS

1) The minettes in the Milk River area southern Alberta, have had a complex petrogenesis. The compositions of the olivine minettes may be consistent with derivation by partial melting of olivine, clinopyroxene and phlogopite bearing sources at pressures >17 kb.

2) Isotopic and trace element compositions require a multistage petrogenetic model involving three separate components: 1) LREE enriched, HFSE depleted and has low $^{143}Nd/^{144}Nd$ ratios and is most likely an ancient lithospheric mantle source. 2) Asthenospheric mantle source with $^{87}Sr/^{86}Sr$ and ε_{Nd} of around bulk earth composition. 3) A young component characterized by high $^{87}Sr/^{86}Sr$, Rb/Sr and Sm/Nd representing LILE and LREE enriched lithosphere.

3) The suite of minettes are the products of polybaric evolution by fractional crystallization of olivine, clinopyroxene and phlogopite, which produced a range of variably-evolved daughters with phenocrysts assemblages of phlogopite, clinopyroxene ± olivine. The mica-clinopyroxenite nodules are believed to represent a higher pressure, hydrous assemblage fractionated from the minettes possibly in the upper mantle. Variable degrees of mixing between magmas containing higher and lower temperature assemblages contributed to additional diversification within the group.

Chapter 6

Summary and Conclusions

MINETTES, MICA-CLINOPYROXENITES AND THEIR MINERALOGY

The Milk River minettes in southern Alberta represent northern outliers of the Eocene-age Sweetgrass Hills igneous complex of Montana. The exposures occur as dikes, sills and plugs as well as extrusive rocks. A suite of cognate mica-clinopyroxenite inclusions has been collected from one of these exposures, Coulee 29, a minette vent complex consisting of several distinct magmatic packages, some of which contain a variety of xenoliths. The minettes have a porphyritic texture consisting of phenocrysts of phlogopite, diopside and olivine pseudomorphs in a groundmass of sanidine, analcite, mica, clinopyroxene, apatite and titanomagnetite. The mica-clinopyroxenite inclusions are generally coarse grained and have varying proportions of phlogopite, diopside and apatite. Some inclusions show layered textures suggestive of a cumulate origin.

Zoning in Clinopyroxenes and Micas

Complex compositional zoning and resorption of the clinopyroxene and phlogopite phenocrysts in the minettes and clinopyroxene and phlogopite in the inclusions is described in Chapter 2. In a study of the mineralogy, chemistry, and origin of the potassic mafic lavas of the Bearpaw Mountains, Macdonald *et al.* (1992) describes clinopyroxenes in minettes that show oscillatory zoning comparable to those in minettes and nodules of this study. In an exhaustive electron microbeam and textural analytical study of clinopyroxenes in minettes and "mafic phonolites" of the Highwood Mountains, O'Brien *et al.* (1988) showed that zoning similar to that in the Bearpaw rocks and the rocks in this study, were a result of repeated mixing events between batches of variably fractionated and degassed "mafic phonolite" and primitive undegassed minette magma. Variable and complex zoning also occurs in phenocrystal micas from the Milk River minettes. O'Brien *et al.* (1988) have described similarly complex zoned micas from mixed "mafic phonolite" of the Highwood Mountains and have attributed this phenomenon to separate episodes of growth in a minette-dominated mixed magma.

RELATIONSHIP OF THE MICA-CLINOPYROXENITES TO THE MINETTE

Fractional Crystallization

The whole rock and selected trace element chemistry of nine minettes, one diorite porphyry and seven mica-clinopyroxenite inclusions were determined by XRF, ICP and INAA methods by Activation Laboratories Ltd.

The most primitive minette samples are black *olivine minettes* (Mg# >70, 11-14 wt.% MgO, Ni 450-664 ppm, Cr 750-960 ppm), some of which host a suite of lower crustal xenoliths as well as cognate mica-clinopyroxenites. Systematic trends of major and trace elements on variation diagrams are consistent with a model of fractional crystallization of olivine minette magmas by removal of olivine, mica, and clinopyroxene. The composition of the mica-clinopyroxenite nodules lie on extrapolations of the trends for MgO vs. Al_2O_3, CaO, and SiO_2 of the minettes. This relationship is consistent with the nodules being cumulates extracted from the evolving parental magma. The good correlation between CaO, K_2O and MgO suggests the importance of clinopyroxene and phlogopite fractionation.

The overall greater concentrations in REE in the minettes relative to the mica-clinopyroxenite inclusions is consistent with the subtraction of phlogopite, clinopyroxene (with low D values for REE) and minor apatite from the minettes.

The minettes are the products of polybaric evolution by fractional crystallization of olivine, clinopyroxene and phlogopite to produce a range of variably evolved daughters with phenocrysts assemblages of phlogopite, clinopyroxene ± olivine. The mica-clinopyroxenite nodules represent a higher pressure, hydrous assemblage fractionated from the minettes possibly in the upper mantle. Variable degrees of mixing between magmas containing higher and lower temperature assemblages contributed to additional diversification within the group.

CHARACTERIZATION OF SOURCE REGIONS

Mineralogy and Lithology of Source Region

Comparison of the minette compositions with the experimental phase relations (in the augite-olivine-sanidine pseudoternary system) show that the primary Milk River minettes could have been generated at pressures greater than 17 kb from a mantle source containing olivine, clinopyroxene and phlogopite. The K-rich, yet magnesian nature of the Milk River minettes is consistent with a significant contribution from phlogopite in the source region of the minettes. More direct evidence of the petrologic nature of deep-seated materials that contributed to minette magmas in the Wyoming province, comes from ultramafic xenolith suites in Eocene minettes from the Bearpaw Mountains, Highwood Mountains and Eagle Buttes, Montana. These xenoliths, phlogopite bearing, veined peridotites from the Highwood, Bearpaw and Eagle Butte minettes may represent ancient metasomatically modified, residual, lithospheric mantle as suggested by O'Brien *et al.* (1991), Macdonald *et al.* (1992) and Carlson and Irving, (1994).

Isotopic Compositions

The isotopic compositions of the Milk River magmas occupy similar portions in ε_{Nd}-$^{87}Sr/^{86}Sr$ and $^{208}Pb/^{206}Pb$, $^{207}Pb/^{206}Pb$ space as other Wyoming Province samples. Both the Milk River minettes and the mica-clinopyroxenite inclusions from Coulee 29 have similar isotopic compositions. Calculated Rb-Sr ages for two mica-clinopyroxenites and a minette dike, from Coulee 29, are in agreement with previous age determinations, by others, for rocks from the Sweetgrass Hills igneous complex. The Milk River minettes show Sm/Nd model ages relative to CHUR ranging from 1.3 to 1.8 Ga.

The Milk River minettes have trace element and isotopic characteristics that are explicable by a three component source model as has been recognized for other rocks of the Wyoming province by Irving *et al.* (1988), Macdonald *et al.* (1992), O'Brien *et al.* (1991) and Scambos and Farmer (1988). The first component is LREE enriched, HFSE depleted with low $^{143}Nd/^{144}Nd$ ratios. Phlogopite bearing peridotite xenoliths in the Bearpaw, Highwood and Eagle Butte minettes, Montana, may be representative of this component in the ancient, subcontinental lithospheric mantle. The second end-member is an asthenospheric component and is recognizable as the dominant component in the essentially coeval kimberlitic rocks of the Missouri Breaks as well as the monticellite peridotite/alnoite diatremes of Haystack Butte. Additionally, the third component, is characterized by high $^{87}Sr/^{86}Sr$, Rb/Sr and Sm/Nd within the minettes. This component also shows a lack of correlation between $^{87}Sr/^{86}Sr$ and Rb/Sr suggesting that it is young. The nature of the enrichment mechanism for this third component is still being debated (e.g., O'Brien *et al.*, 1991, Macdonald *et al.*, 1992) and remains unknown.

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Appendix A

Petrographic descriptions of Representative Milk River Samples

The following brief descriptions provide examples of the major rock types discussed in the text.

MINETTE

OC7-1 *Olivine Minette*
This sample is dark greenish-brown to black in hand sample. Seriate porphyritic texture with phenocrysts of diopside (0.1-1.5mm), phlogopite (0.1-3mm) and olivine pseudomorphs (1-3mm). The brownish groundmass consists of mica, salite, sanidine, apatite needles, carbonate, analcime and titanomagnetite (all < 0.05mm). Phlogopite can be slightly rounded and embayed.

OC8-16 *Olivine Minette*
It is black in hand sample and is very similar to OC7-1, but it has a slightly different texture. The groundmass is finer grained and appears partly altered under low magnification.

Au90-24-1 *Olivine Minette*
Seriate porphyritic with phlogopite (0.1-2mm) that are rounded and embayed, some with characteristic zoning from yellowish cores to reddish brown pleochroic rims, subhedral-euhedral clinopyroxene (0.1-1.5mm), olivine pseudomorphs (0.5-2.5mm) in a microgranular groundmass of mica tablets, sanidine, apatite needles, carbonate, analcime and titanomagnetite.

MR92-09 *minette*

Seriate-hiatal porphyritic with subhedral-euhedral phlogopite (0.3-3.5mm), and diopside in a microgranular matrix consisting of clinopyroxene, mica, oxides and sanidine in a feathery, radiating and tablet habit.

G70-11-7 *felsic minette*

This sample is light brown in hand sample, is fine grained and has a trachytoid/seriate porphyritic texture with phenocrysts of phlogopite, some salite in a microgranular matrix rich in K-feldspar (feathery, radiating and tablet habit) and biotite, with some titanomagnetite.

MICA CLINOPYROXENITES

DAT4-5

Consisting of alternating layers of phlogopite and clinopyroxene, some layers are completely monomineralic and granular. Large grain size variation within a single thin section (e.g., phlogopite 0.3-5mm and diopside 0.1-3mm). Phlogopite blades and poikilitic, euhedral-subhedral. Apatite is rare.

OC8-6

This sample consists of bladed as well as poikilitic phlogopite (0.3-1.5mm). Clinopyroxene is granular, anhedral-subhedral (0.3-1.5mm). Clinopyroxene and phlogopite form a framework of interfering plates and laths. Subhedral to euhedral apatite (0.1-0.75mm). Carbonate (dolomite or calcite) is sometimes observed between cleavage planes of phlogopite or filling voids. Titanomagnetite is rare.

OC-8-9

Is very similar to OC8-6 but coarser grained with tablet and poikilitic phlogopite (0.5-3mm). Anhedral-subhedral clinopyroxene (0.3-3mm) with subhedral-euhedral apatite (0.1-1mm).

Au26-5

Contains dark brown coarse grained tablet and poikilitic phlogopite (1-7mm) with anhedral-subhedral clinopyroxene (0.3-1.5mm). Clinopyroxenes and micas form a framework of interfering plates and laths. Apatite is coarse grained (0.3-1.5mm) and is subhedral to euhedral. Carbonate filling spaces between clinopyroxene is sometimes observed. Titanomagnetite is rare.

Au26-10

This sample is very similar to Au26-5 but coarser grained. With dark brown tablets of phlogopite (0.8-15mm), subhedral-euhedral clinopyroxene (1-6mm) and euhedral apatite (0.2-2mm).

Appendix B

Microprobe Data

This appendix gives mineral compositions of clinopyroxene, mica, apatite, feldspar and oxides for the samples from Coulee 29, Milk River Area, Southern Alberta that were acquired by wavelength dispersive electron microprobe analyses at the Department of Earth and Atmospheric Sciences, University of Alberta. Clinopyroxene and mica spot analyses were conducted on an ARL SEMQ microprobe. Clinopyroxene and mica line scan, apatite, feldspar and oxide analyses were determined on a JEOL 8900R microprobe. Typical analytical conditions for all probe data as follows: 15kV acceleration potential, 10-12nA beam current, a 1-10 μm beam diameter and a 20 second peak count integration time. Natural minerals were used as standards. Clinopyroxene and mica spot analyses data were corrected with a phi-rho-z program provided by Tracor Northern, data for clinopyroxene and mica line scans, apatite, feldspar and oxides were corrected with a ZAF program provided by JEOL.

There are five tables to this appendix, the first two (clinopyroxene and mica) are the largest reflecting the character of the work described in Chapter 2. The next pages of this appendix represent a key to the tables of analyses of clinopyroxene, mica, apatite, feldspar and oxides.

CLINOPYROXENE

FeO is the measured value of Fe, Fe_2O_3 were calculated with the method of Droop (1987).

Table B.1a: Spot analyses of clinopyroxene phenocrysts from olivine minette OC7-1; Groundmass clinopyroxene compositions from olivine minette OC7-1; Line scan traverse across a phenocryst from olivine minette OC7-1. (74-81)

Table B.1b: Spot analyses of clinopyroxene phenocrysts from olivine minette OC8-16; Line scan traverse across a clinopyroxene phenocryst from olivine minette OC8-16 (used to construct Fig. 2.10 in Chapter 2). (82-87)

Table B.1c: Spot analyses of clinopyroxenes from mica-clinopyroxenite nodule DAT4-5.

Table B.1d: Spot analyses of clinopyroxenes from mica-clinopyroxenite nodule OC8-6; Line scan traverse across a clinopyroxene crystal from mica-clinopyroxenite OC8-6 (used to construct Fig. 2.11 in Chapter 2). (89-94)

Table B.1e: Spot analyses of clinopyroxenes from mica-clinopyroxenite nodule OC8-9. (95)

Table B.1f: Spot analyses of clinopyroxenes from mica-clinopyroxenite nodule OC8-12. (96-97)

Table B.1g: Spot analyses of clinopyroxenes from mica-clinopyroxenite nodule OC8-17. (98-99)

Table B.1h: Spot analyses of clinopyroxenes from mica-clinopyroxenite nodule AU26-5. (100)

Table B.1i: Spot analyses of clinopyroxenes from mica-clinopyroxenite nodule AU26-10. (101)

MICA

Table B.2a: Spot analyses of mica phenocrysts from olivine minette OC7-1; Groundmass mica compositions from olivine minette OC7-1. (102-103)

Table B.2b: Line scan traverse across a mica phenocryst from olivine minette OC8-16 (used to construct Fig. 2.13 in Chapter 2); Line scan traverse across another mica phenocryst from olivine minette OC8-16. (104-110)

Table B.2c: Spot analyses of micas from mica-clinopyroxenite nodule DAT4-5. (111)

Table B.2d: Spot analyses of micas from mica-clinopyroxenite nodule OC8-6; Line scan traverse across a mica crystal from mica-clinopyroxenite nodule OC8-6. (112-114)

Table B.2e: Spot analyses of micas from mica-clinopyroxenite nodule OC8-9. (115)

Table B.2f: Spot analyses of micas from mica-clinopyroxenite nodule OC8-12. (116)
Table B.2g: Spot analyses of micas from mica-clinopyroxenite nodule OC8-17. (117)
Table B.2h: Spot analyses of micas from mica-clinopyroxenite nodule AU26-5. (118)
Table B.2i: Spot analyses of micas from mica-clinopyroxenite nodule AU26-10. (119)

APATITE

Table B.3a: Groundmass apatite compositions from olivine minette OC7-1. (120)
Table B.3b: Groundmass apatite compositions from olivine minette OC8-16. (121)
Table B.3c: Spot analyses of apatites from mica-clinopyroxenite OC8-6. (122)
Table B.3d: Spot analyses of apatites from mica-clinopyroxenite OC8-9. (123)
Table B.3e: Spot analyses of apatites from mica-clinopyroxenite OC8-17. (124)
Table B.3f: Spot analyses of apatites from mica-clinopyroxenite AU26-5. (125)
Table B.3g: Spot analyses of apatites from mica-clinopyroxenite AU26-10. (126)

ALKALI FELDSPAR

Table B.4a: Groundmass alkali feldspar compositions from olivine minette OC7-1. (127)
Table B.4b: Groundmass alkali feldspar compositions from olivine minette OC8-16. (128)

OXIDES

Table B.5a: Groundmass oxide compositions from olivine minette OC7-1. (129-130)
Table B.5b: Groundmass oxide compositions from olivine minette OC8-16. (131-132)

Table B.1a

OC7-1 Clinopyroxene Phenocryst Compositions

	CORE 1,1	*BAND 1,1,2*	*BAND 1,2,3*	*BAND 1,3,4*	*BAND 1,4,5*	*BAND 1,5,6*	*CORE 2,1*	*RIM 2,2*	*CORE 4,1*	*RIM 4,2*	*RIM 4,3*	*CORE 5,1*
SiO2	52.83	53.99	54.01	53.75	54.34	52.95	53.47	52.81	53.41	53.67	54.20	53.15
TiO2	0.22	0.19	0.16	0.21	0.18	0.33	0.18	0.42	0.21	0.24	0.22	0.31
Al2O3	1.82	0.85	0.72	0.76	0.70	0.87	0.98	1.14	0.83	0.94	0.77	0.82
Cr2O3	0.00	0.02	0.15	0.07	0.16	0.30	0.05	0.36	0.04	0.02	0.17	0.01
Fe2O3	2.60	2.11	2.48	3.05	1.66	3.42	3.18	3.64	2.85	2.93	1.84	2.94
FeO	4.04	2.91	2.07	2.40	2.67	1.86	2.78	1.99	2.20	3.47	2.18	2.71
MnO	0.21	0.15	0.06	0.16	0.11	0.23	0.17	0.15	0.14	0.23	0.14	0.17
MgO	16.18	18.43	18.40	18.48	18.39	17.60	18.63	17.40	18.07	17.68	18.49	17.44
CaO	21.56	21.73	22.48	21.72	22.21	22.58	20.75	22.69	22.12	21.54	22.24	22.43
Na2O	0.57	0.21	0.22	0.25	0.24	0.27	0.29	0.28	0.25	0.34	0.26	0.24
K20	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.03	100.59	100.75	100.87	100.67	100.40	100.48	100.89	100.12	101.06	100.50	100.21
Cations Based on 6 Oxygens												
Si	1.939	1.955	1.952	1.944	1.964	1.931	1.940	1.919	1.946	1.945	1.960	1.942
Ti	0.006	0.005	0.004	0.006	0.005	0.009	0.005	0.011	0.006	0.007	0.006	0.009
Al	0.079	0.036	0.031	0.032	0.030	0.037	0.042	0.049	0.036	0.040	0.033	0.035
Cr	0.000	0.001	0.004	0.002	0.004	0.009	0.001	0.010	0.001	0.001	0.005	0.000
Fe3	0.072	0.057	0.067	0.083	0.045	0.094	0.087	0.100	0.078	0.080	0.050	0.081
Fe2	0.124	0.088	0.062	0.073	0.081	0.057	0.084	0.060	0.067	0.105	0.066	0.083
Mn	0.006	0.005	0.002	0.005	0.003	0.007	0.005	0.005	0.004	0.007	0.004	0.005
Mg	0.885	0.995	0.991	0.996	0.991	0.956	1.008	0.942	0.981	0.955	0.996	0.950
Ca	0.848	0.843	0.870	0.842	0.860	0.882	0.807	0.884	0.863	0.836	0.862	0.878
Na	0.041	0.015	0.015	0.017	0.017	0.019	0.021	0.020	0.018	0.024	0.019	0.017
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.364	3.604	3.657	3.593	3.652	3.583	3.538	3.540	3.606	3.498	3.661	3.565
mg	81.9	87.2	88.4	86.5	88.7	86.4	85.5	85.5	87.1	83.8	89.6	85.3
FEO*	6.38	4.81	4.30	5.15	4.16	4.93	5.64	5.27	4.76	6.11	3.83	5.35
Wo	44.0	42.5	43.7	42.2	43.5	44.3	40.6	44.5	43.4	42.3	43.7	44.1
En	45.9	50.2	49.8	50.0	50.1	48.1	50.8	47.4	49.3	48.3	50.5	47.7
Fs	10.2	7.3	6.5	7.8	6.4	7.6	8.6	8.1	7.3	9.4	5.9	8.2

Table B.1a (cont.)

OC7-1 Clinopyroxene Phenocryst Compositions

	RIM 5,2	*CORE 6,1*	*RIM 6,2*	*CORE 7,1*	*RIM 7,2*	*RIM 8,1*	*MID 8,2*	*CORE 8,3*	*CORE 9,1*	*CORE 9,2*	*CORE 9,3*	*RIM 9,4*
SiO2	51.35	53.64	53.01	51.67	50.79	54.33	54.26	53.92	54.30	53.87	51.27	52.51
TiO2	0.55	0.19	0.36	0.44	0.70	0.19	0.21	0.24	0.27	0.25	0.34	0.72
Al2O3	1.47	0.65	1.11	1.74	2.04	0.79	0.69	1.10	1.06	1.00	2.52	1.95
Cr2O3	0.29	0.23	0.37	0.12	0.25	0.11	0.00	0.00	0.01	0.06	0.04	0.22
Fe2O3	4.60	3.01	3.49	4.93	4.61	2.28	1.35	1.98	1.41	2.12	4.89	2.81
FeO	1.52	1.96	1.67	0.91	2.26	2.78	3.75	4.53	4.08	3.46	7.73	4.02
MnO	0.12	0.09	0.17	0.14	0.13	0.15	0.11	0.20	0.21	0.19	0.33	0.10
MgO	16.49	18.74	17.65	17.58	15.89	19.05	18.50	17.17	17.30	17.41	11.00	16.07
CaO	22.91	21.70	22.52	21.96	22.50	21.30	21.12	21.67	22.25	22.43	20.49	22.50
Na2O	0.32	0.22	0.34	0.36	0.38	0.20	0.24	0.33	0.33	0.27	1.66	0.36
K20	0.00	0.01	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.05
Total	99.62	100.44	100.69	99.85	99.57	101.18	100.23	101.14	101.22	101.06	100.27	101.31
Cations Based on 6 Oxygens												
Si	1.896	1.944	1.925	1.893	1.882	1.953	1.970	1.955	1.963	1.951	1.925	1.911
Ti	0.015	0.005	0.010	0.012	0.020	0.005	0.006	0.007	0.007	0.007	0.009	0.020
Al	0.064	0.028	0.048	0.075	0.089	0.033	0.030	0.047	0.045	0.042	0.112	0.084
Cr	0.009	0.007	0.011	0.003	0.007	0.003	0.000	0.001	0.000	0.002	0.001	0.006
Fe3	0.128	0.082	0.096	0.136	0.129	0.062	0.037	0.054	0.038	0.058	0.138	0.077
Fe2	0.047	0.059	0.051	0.028	0.070	0.083	0.114	0.137	0.123	0.105	0.243	0.122
Mn	0.004	0.003	0.005	0.004	0.004	0.005	0.003	0.006	0.006	0.006	0.011	0.003
Mg	0.908	1.013	0.956	0.960	0.878	1.021	1.001	0.928	0.932	0.940	0.616	0.872
Ca	0.906	0.843	0.876	0.862	0.893	0.820	0.821	0.842	0.862	0.870	0.824	0.878
Na	0.023	0.016	0.024	0.025	0.027	0.014	0.017	0.023	0.023	0.019	0.121	0.026
K	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.002
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.475	3.638	3.564	3.477	3.358	3.613	3.597	3.467	3.524	3.544	2.765	3.357
mg	83.9	87.7	86.7	85.4	81.6	87.5	86.9	82.9	85.2	85.2	61.8	81.4
FEO*	5.66	4.67	4.81	5.35	6.41	4.83	4.96	6.31	5.35	5.37	12.13	6.55
Wo	45.6	42.2	44.3	43.4	45.3	41.3	41.6	42.9	44.1	44.1	45.3	45.0
En	45.6	50.7	48.3	48.3	44.6	51.4	50.7	47.3	47.7	47.6	33.8	44.7
Fs	8.8	7.1	7.4	8.2	10.1	7.3	7.6	9.8	8.3	8.2	20.9	10.2

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1a

OC7-1 Clinopyroxene Groundmass Compositions

	GM 1	*GM 3*	*GM 5*	*GM 6*	*GM 7*	*GM 8*	*GM 9*	*GM 11*	*GM 12*	*GM 13*	*GM 14*	*GM 15*
SiO2	50.58	52.53	50.00	52.82	51.87	51.82	51.75	52.21	51.75	53.39	50.33	52.21
TiO2	0.86	0.72	1.06	0.65	0.95	0.72	0.70	0.83	1.03	0.66	1.07	0.75
Al2O3	3.15	1.54	2.91	1.47	2.00	1.93	2.19	2.06	2.49	1.51	2.43	1.72
Cr2O3	0.00	0.05	0.08	0.07	0.02	0.03	0.15	0.00	0.48	0.03	0.02	0.00
Fe2O3	4.66	3.48	5.86	2.19	2.95	2.82	4.76	3.72	3.83	2.08	5.34	3.80
FeO	6.28	4.06	2.77	4.86	5.55	5.65	3.10	4.71	3.19	5.19	3.79	4.43
MnO	0.29	0.20	0.16	0.14	0.27	0.29	0.13	0.29	0.14	0.18	0.25	0.29
MgO	12.83	16.40	15.12	16.20	15.30	14.80	15.84	15.34	16.11	16.26	15.06	15.87
CaO	21.13	22.06	22.30	22.18	21.72	22.00	22.63	22.37	22.27	22.21	21.89	22.13
Na2O	0.72	0.33	0.45	0.28	0.34	0.40	0.40	0.40	0.43	0.32	0.40	0.34
K20	0.47	0.06	0.07	0.05	0.13	0.09	0.06	0.10	0.07	0.06	0.12	0.05
Total	100.97	101.43	100.78	100.91	101.11	100.55	101.72	102.03	101.79	101.89	100.69	101.59
Cations Based on 6 Oxygens												
Si	1.879	1.912	1.843	1.930	1.904	1.915	1.882	1.899	1.876	1.933	1.860	1.904
Ti	0.024	0.020	0.029	0.018	0.026	0.020	0.019	0.023	0.028	0.018	0.030	0.020
Al	0.138	0.066	0.126	0.063	0.087	0.084	0.094	0.088	0.106	0.065	0.106	0.074
Cr	0.000	0.001	0.002	0.002	0.001	0.001	0.004	0.000	0.014	0.001	0.000	0.000
Fe3	0.130	0.095	0.162	0.060	0.082	0.078	0.130	0.102	0.105	0.057	0.148	0.104
Fe2	0.195	0.124	0.085	0.148	0.171	0.175	0.094	0.143	0.097	0.157	0.117	0.135
Mn	0.009	0.006	0.005	0.004	0.008	0.009	0.004	0.009	0.004	0.006	0.008	0.009
Mg	0.710	0.890	0.831	0.883	0.837	0.815	0.859	0.832	0.871	0.878	0.830	0.863
Ca	0.841	0.860	0.881	0.869	0.854	0.871	0.882	0.872	0.865	0.862	0.867	0.864
Na	0.052	0.023	0.032	0.020	0.024	0.028	0.028	0.028	0.030	0.022	0.029	0.024
K	0.022	0.003	0.003	0.002	0.006	0.004	0.003	0.005	0.003	0.003	0.006	0.002
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	2.913	3.356	3.158	3.387	3.221	3.227	3.293	3.236	3.284	3.365	3.159	3.293
mg	68.6	80.3	77.0	80.9	76.8	76.3	79.3	77.2	81.2	80.4	75.8	78.3
FEO*	10.47	7.19	8.04	6.83	8.21	8.19	7.39	8.06	6.64	7.06	8.59	7.85
Wo	44.8	43.7	45.0	44.3	44.0	44.9	44.9	44.7	44.7	44.1	44.2	44.0
En	37.9	45.2	42.4	45.0	43.1	42.0	43.7	42.7	44.9	44.9	42.3	43.9
Fs	17.3	11.1	12.6	10.7	13.0	13.1	11.4	12.6	10.4	10.9	13.5	12.2

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1a

OC 7-1 Clinopyroxene Line Scan Traverse

	97	*98*	*99*	*100*	*101*	*102*	*103*	*104*	*105*	*106*	*107*	*108*
SiO2	54.49	49.04	48.76	51.03	51.99	52.26	52.17	53.77	53.65	37.88	53.88	53.84
TiO2	0.03	1.01	0.95	0.60	0.68	0.60	0.39	0.35	0.35	0.26	0.29	0.26
Al2O3	21.67	2.50	2.33	1.61	1.91	1.67	1.06	0.85	0.80	0.72	0.86	0.91
Cr2O3	0.00	0.01	0.05	0.13	0.10	0.16	0.15	0.21	0.27	0.25	0.42	0.46
Fe2O3	-26.88	6.04	7.12	4.42	3.79	3.57	3.40	1.59	1.82	25.84	1.39	1.03
FeO	26.60	2.64	1.12	2.48	3.27	3.16	2.70	4.00	3.43	-20.00	3.07	3.58
MnO	0.03	0.22	0.21	0.16	0.14	0.14	0.15	0.15	0.14	0.10	0.15	0.14
MgO	3.80	14.10	14.83	15.29	15.69	15.88	16.08	16.95	17.13	12.01	17.23	17.15
CaO	0.69	22.90	22.89	23.16	22.95	23.16	23.28	22.73	22.80	33.47	23.15	22.67
Na2O	4.87	0.41	0.40	0.38	0.39	0.36	0.28	0.23	0.24	0.23	0.24	0.26
K20	2.72	0.09	0.07	0.07	0.05	0.04	0.04	0.03	0.02	0.03	0.01	0.01
Total	88.02	98.96	98.73	99.33	100.97	100.99	99.69	100.85	100.64	90.79	100.66	100.31
Cations Based on 6 Oxygens												
Si	2.149	1.847	1.836	1.899	1.902	1.909	1.927	1.956	1.953	1.575	1.957	1.962
Ti	0.001	0.028	0.027	0.017	0.019	0.017	0.011	0.010	0.009	0.008	0.008	0.007
Al	1.007	0.111	0.103	0.071	0.082	0.072	0.046	0.036	0.034	0.035	0.037	0.039
Cr	0.000	0.000	0.001	0.004	0.003	0.005	0.004	0.006	0.008	0.008	0.012	0.013
Fe3	-0.798	0.171	0.202	0.124	0.104	0.098	0.095	0.044	0.050	0.809	0.038	0.028
Fe2	0.878	0.083	0.035	0.077	0.100	0.097	0.083	0.122	0.104	-0.696	0.093	0.109
Mn	0.001	0.007	0.007	0.005	0.004	0.004	0.005	0.004	0.004	0.004	0.004	0.004
Mg	0.223	0.792	0.833	0.848	0.856	0.865	0.885	0.919	0.930	0.744	0.933	0.932
Ca	0.029	0.924	0.923	0.924	0.899	0.907	0.922	0.886	0.889	1.492	0.901	0.885
Na	0.373	0.030	0.029	0.028	0.028	0.025	0.020	0.016	0.017	0.018	0.017	0.019
K	0.137	0.004	0.003	0.003	0.002	0.002	0.002	0.001	0.001	0.002	0.000	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	0.882	3.178	3.245	3.389	3.351	3.401	3.507	3.548	3.576	3.904	3.618	3.595
mg	73.7	75.7	77.8	80.8	80.7	81.6	83.3	84.8	85.8	86.8	87.7	87.2
FEO*	2.41	8.08	7.52	6.46	6.68	6.37	5.76	5.43	5.07	3.25	4.32	4.51
Wo	8.8	46.9	46.3	46.8	45.9	46.1	46.4	45.0	45.1	63.5	45.9	45.3
En	67.2	40.2	41.8	43.0	43.7	44.0	44.6	46.7	47.1	31.7	47.5	47.7
Fs	23.9	12.9	11.9	10.2	10.4	9.9	9.0	8.4	7.8	4.8	6.7	7.0

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	109	*110*	*111*	*112*	*113*	*114*	*115*	*116*	*117*	*118*	*119*	*120*
SiO2	54.20	54.08	54.53	54.31	53.75	53.39	53.35	53.51	53.90	54.04	54.14	53.97
TiO2	0.21	0.17	0.20	0.19	0.26	0.23	0.26	0.21	0.20	0.20	0.22	0.20
Al2O3	0.77	0.79	0.77	0.91	1.28	1.35	1.20	0.94	0.83	0.81	0.91	0.88
Cr2O3	0.43	0.11	0.23	0.30	0.09	0.29	0.07	0.02	0.04	0.02	0.04	0.02
Fe2O3	1.55	1.06	-0.26	-0.45	0.69	1.19	1.20	0.70	1.47	0.72	0.16	0.91
FeO	2.72	3.60	4.44	4.74	5.94	5.57	6.62	6.69	6.08	6.20	6.52	5.62
MnO	0.10	0.11	0.14	0.13	0.20	0.22	0.24	0.24	0.22	0.23	0.20	0.20
MgO	17.60	17.91	17.60	17.77	16.89	16.40	15.69	15.89	16.44	16.47	16.45	16.72
CaO	23.03	21.81	21.96	21.36	20.80	21.10	21.33	21.24	21.21	21.28	21.32	21.50
Na2O	0.27	0.26	0.27	0.23	0.34	0.41	0.39	0.35	0.38	0.35	0.33	0.32
K20	0.02	0.02	0.02	0.04	0.02	0.02	0.01	0.03	0.03	0.03	0.01	0.02
Total	100.88	99.92	99.90	99.55	100.25	100.17	100.37	99.83	100.79	100.34	100.31	100.36
Cations Based on 6 Oxygens												
Si	1.961	1.972	1.988	1.986	1.967	1.959	1.964	1.977	1.970	1.980	1.983	1.974
Ti	0.006	0.005	0.006	0.005	0.007	0.006	0.007	0.006	0.005	0.005	0.006	0.005
Al	0.033	0.034	0.033	0.039	0.055	0.058	0.052	0.041	0.036	0.035	0.039	0.038
Cr	0.012	0.003	0.007	0.009	0.003	0.008	0.002	0.001	0.001	0.000	0.001	0.001
Fe3	0.042	0.029	-0.007	-0.012	0.019	0.033	0.033	0.019	0.040	0.020	0.004	0.025
Fe2	0.082	0.110	0.135	0.145	0.182	0.171	0.204	0.207	0.186	0.190	0.200	0.172
Mn	0.003	0.003	0.004	0.004	0.006	0.007	0.008	0.007	0.007	0.007	0.006	0.006
Mg	0.949	0.973	0.956	0.969	0.921	0.897	0.861	0.875	0.896	0.900	0.898	0.912
Ca	0.893	0.852	0.858	0.837	0.816	0.830	0.841	0.841	0.831	0.836	0.837	0.843
Na	0.019	0.018	0.019	0.017	0.024	0.029	0.028	0.025	0.027	0.025	0.023	0.023
K	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.643	3.610	3.617	3.599	3.418	3.399	3.344	3.393	3.408	3.439	3.442	3.468
mg	88.4	87.5	88.2	87.9	82.1	81.5	78.4	79.5	79.8	81.1	81.5	82.2
FEO*	4.11	4.55	4.20	4.34	6.55	6.64	7.70	7.32	7.40	6.85	6.67	6.44
Wo	45.4	43.4	44.2	43.2	42.1	43.0	43.4	43.3	42.5	43.0	43.1	43.2
En	48.3	49.5	49.2	50.0	47.5	46.5	44.4	45.1	45.9	46.3	46.3	46.7
Fs	6.3	7.1	6.6	6.8	10.4	10.6	12.2	11.6	11.6	10.8	10.5	10.1

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	121	*122*	*123*	*124*	*125*	*126*	*127*	*128*	*129*	*130*	*131*	*132*
SiO2	53.53	53.93	53.99	53.72	54.05	53.99	53.47	44.89	53.29	53.66	53.84	53.81
TiO2	0.24	0.20	0.19	0.18	0.22	0.20	0.28	0.22	0.42	0.29	0.30	0.29
Al2O3	0.81	0.76	0.77	0.77	0.85	0.86	0.97	2.47	1.49	1.11	0.99	1.03
Cr2O3	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.03	0.00	0.04	0.02	0.06
Fe2O3	3.15	2.49	2.46	2.01	2.15	2.09	2.25	1.37	2.20	2.15	1.13	2.03
FeO	3.02	3.35	3.41	3.65	3.35	3.12	3.36	10.26	4.20	3.51	4.24	3.38
MnO	0.18	0.16	0.16	0.18	0.13	0.15	0.15	0.12	0.17	0.13	0.16	0.13
MgO	17.24	17.31	17.30	17.20	17.26	17.24	17.06	14.77	16.63	17.02	16.99	17.06
CaO	22.46	22.43	22.47	22.39	22.76	22.77	22.57	12.31	21.99	22.71	22.22	22.74
Na2O	0.32	0.32	0.31	0.25	0.28	0.33	0.29	0.22	0.40	0.27	0.31	0.33
K20	0.02	0.02	0.03	0.02	0.04	0.02	0.01	0.12	0.02	0.03	0.01	0.00
Total	100.97	100.97	101.10	100.40	101.07	100.75	100.39	86.77	100.81	100.92	100.21	100.86
Cations Based on 6 Oxygens												
Si	1.945	1.956	1.956	1.960	1.958	1.960	1.951	1.920	1.941	1.949	1.966	1.953
Ti	0.006	0.006	0.005	0.005	0.006	0.005	0.008	0.007	0.012	0.008	0.008	0.008
Al	0.035	0.032	0.033	0.033	0.036	0.037	0.042	0.124	0.064	0.047	0.043	0.044
Cr	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.002
Fe3	0.086	0.068	0.067	0.055	0.059	0.057	0.062	0.044	0.060	0.059	0.031	0.056
Fe2	0.092	0.102	0.103	0.111	0.102	0.095	0.103	0.367	0.128	0.106	0.129	0.103
Mn	0.005	0.005	0.005	0.006	0.004	0.004	0.005	0.004	0.005	0.004	0.005	0.004
Mg	0.934	0.936	0.935	0.935	0.932	0.933	0.928	0.942	0.903	0.921	0.925	0.923
Ca	0.874	0.872	0.872	0.875	0.883	0.886	0.882	0.564	0.858	0.884	0.869	0.884
Na	0.022	0.023	0.022	0.018	0.020	0.023	0.020	0.018	0.028	0.019	0.022	0.023
K	0.001	0.001	0.001	0.001	0.002	0.001	0.000	0.007	0.001	0.001	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.531	3.549	3.548	3.559	3.564	3.574	3.541	2.874	3.423	3.528	3.531	3.542
mg	84.0	84.7	84.6	84.9	85.3	86.0	85.0	69.6	82.7	84.8	85.2	85.4
FEO*	5.86	5.59	5.63	5.46	5.28	4.99	5.39	11.49	6.18	5.44	5.26	5.21
Wo	44.0	44.1	44.1	44.3	44.7	45.0	44.7	29.4	44.0	44.9	44.5	45.0
En	47.0	47.3	47.3	47.3	47.2	47.4	47.0	49.1	46.3	46.8	47.3	47.0
Fs	9.0	8.6	8.6	8.4	8.1	7.7	8.3	21.4	9.7	8.4	8.2	8.0

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	133	*134*	*135*	*136*	*137*	*138*	*139*	*140*	*141*	*142*	*143*	*144*
SiO2	54.11	54.19	53.92	53.67	53.73	53.62	53.53	53.83	54.15	54.23	54.70	51.61
TiO2	0.26	0.28	0.29	0.29	0.34	0.39	0.40	0.39	0.27	0.29	0.24	0.27
Al2O3	0.99	1.00	1.00	1.09	1.19	1.25	1.29	1.28	0.98	0.91	0.85	1.26
Cr2O3	0.03	0.05	0.04	0.04	0.06	0.03	0.01	0.06	0.08	0.11	0.22	0.02
Fe2O3	1.47	1.53	0.99	2.04	1.88	1.35	1.34	0.84	0.11	0.50	0.00	3.63
FeO	3.86	3.80	4.29	3.33	3.75	4.10	4.13	4.61	4.24	4.04	4.10	5.44
MnO	0.15	0.13	0.11	0.11	0.12	0.12	0.13	0.11	0.13	0.14	0.11	0.23
MgO	17.10	17.26	17.06	17.01	16.90	16.80	16.61	16.76	16.96	17.10	17.45	14.10
CaO	22.69	22.46	22.33	22.73	22.53	22.38	22.71	22.43	22.69	22.70	22.56	22.48
Na2O	0.29	0.33	0.28	0.32	0.36	0.34	0.29	0.29	0.28	0.28	0.29	0.50
K20	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.00
Total	100.97	101.03	100.33	100.64	100.87	100.38	100.44	100.62	99.90	100.33	100.54	99.54
Cations Based on 6 Oxygens												
Si	1.962	1.962	1.966	1.952	1.952	1.956	1.954	1.960	1.979	1.974	1.983	1.931
Ti	0.007	0.007	0.008	0.008	0.009	0.011	0.011	0.011	0.007	0.008	0.007	0.008
Al	0.042	0.042	0.043	0.046	0.051	0.054	0.055	0.055	0.042	0.039	0.036	0.056
Cr	0.001	0.001	0.001	0.001	0.002	0.001	0.000	0.002	0.002	0.003	0.006	0.000
Fe3	0.040	0.042	0.027	0.056	0.051	0.037	0.037	0.023	0.003	0.014	0.000	0.102
Fe2	0.117	0.115	0.131	0.101	0.114	0.125	0.126	0.140	0.130	0.123	0.124	0.170
Mn	0.005	0.004	0.003	0.003	0.004	0.004	0.004	0.003	0.004	0.004	0.003	0.007
Mg	0.924	0.932	0.927	0.922	0.915	0.914	0.904	0.910	0.924	0.928	0.943	0.787
Ca	0.881	0.871	0.872	0.886	0.877	0.875	0.888	0.875	0.888	0.886	0.876	0.902
Na	0.020	0.023	0.020	0.023	0.025	0.024	0.021	0.021	0.020	0.020	0.021	0.036
K	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.548	3.545	3.543	3.540	3.505	3.502	3.503	3.500	3.588	3.587	3.617	3.268
mg	85.5	85.6	85.4	85.4	84.7	84.9	84.7	84.8	87.5	87.1	88.4	74.3
FEO*	5.18	5.17	5.19	5.17	5.44	5.32	5.34	5.37	4.34	4.50	4.10	8.71
Wo	44.9	44.5	44.6	45.1	44.8	44.8	45.4	44.9	45.7	45.4	45.1	46.0
En	47.1	47.5	47.4	46.9	46.8	46.8	46.2	46.7	47.5	47.6	48.5	40.1
Fs	8.0	8.0	8.1	8.0	8.4	8.3	8.3	8.4	6.8	7.0	6.4	13.9

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	145	*146*	*147*	*148*	*149*	*150*	*151*	*152*	*153*	*154*	*155*	*156*
SiO2	51.84	54.67	54.31	54.36	54.13	54.08	54.56	54.80	54.93	54.64	54.60	54.62
TiO2	0.23	0.19	0.20	0.25	0.33	0.21	0.23	0.21	0.22	0.26	0.25	0.23
Al2O3	3.21	0.77	0.85	0.90	1.14	0.85	0.80	0.73	0.79	0.77	0.78	0.87
Cr2O3	0.31	0.24	0.08	0.13	0.18	0.17	0.18	0.17	0.18	0.22	0.19	0.31
Fe2O3	1.21	0.78	0.35	0.21	0.46	0.04	1.20	0.81	0.72	0.93	0.79	1.96
FeO	2.97	3.12	3.69	3.98	4.05	3.98	2.97	3.22	3.31	3.06	3.21	2.25
MnO	0.12	0.11	0.11	0.13	0.14	0.13	0.09	0.09	0.08	0.08	0.10	0.12
MgO	17.97	17.58	17.23	17.18	17.02	17.11	17.76	17.66	17.91	17.70	17.64	17.92
CaO	20.14	23.03	22.85	22.75	22.50	22.66	22.88	23.14	22.97	23.00	23.14	23.26
Na2O	0.26	0.30	0.28	0.29	0.35	0.25	0.29	0.27	0.24	0.29	0.23	0.29
K20	0.02	0.03	0.02	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.03	0.02
Total	98.27	100.81	99.97	100.17	100.30	99.51	100.99	101.10	101.37	100.96	100.94	101.85
					Cations Based on 6 Oxygens							
Si	1.912	1.975	1.980	1.980	1.970	1.982	1.968	1.975	1.973	1.972	1.972	1.955
Ti	0.006	0.005	0.005	0.007	0.009	0.006	0.006	0.006	0.006	0.007	0.007	0.006
Al	0.140	0.033	0.037	0.038	0.049	0.037	0.034	0.031	0.034	0.033	0.033	0.037
Cr	0.009	0.007	0.002	0.004	0.005	0.005	0.005	0.005	0.005	0.006	0.005	0.009
Fe3	0.034	0.021	0.010	0.006	0.013	0.001	0.033	0.022	0.019	0.025	0.022	0.053
Fe2	0.092	0.094	0.113	0.121	0.123	0.122	0.089	0.097	0.099	0.093	0.097	0.067
Mn	0.004	0.003	0.003	0.004	0.004	0.004	0.003	0.003	0.002	0.002	0.003	0.003
Mg	0.988	0.947	0.937	0.932	0.924	0.935	0.955	0.949	0.959	0.952	0.949	0.956
Ca	0.796	0.892	0.893	0.888	0.878	0.890	0.885	0.894	0.884	0.889	0.895	0.892
Na	0.019	0.021	0.020	0.020	0.024	0.018	0.020	0.019	0.017	0.021	0.016	0.020
K	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.422	3.650	3.628	3.609	3.558	3.624	3.638	3.652	3.650	3.646	3.652	3.642
mg	88.8	89.1	88.5	88.0	87.2	88.3	88.7	88.9	89.0	89.0	88.9	88.8
FEO*	4.06	3.83	4.01	4.17	4.46	4.02	4.05	3.94	3.96	3.90	3.93	4.01
Wo	41.7	45.6	45.8	45.6	45.3	45.7	45.1	45.6	45.1	45.4	45.6	45.3
En	51.8	48.5	48.0	47.9	47.7	48.0	48.7	48.4	48.9	48.6	48.4	48.6
Fs	6.6	5.9	6.3	6.5	7.0	6.3	6.2	6.1	6.1	6.0	6.0	6.1

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	157	*158*	*159*	*160*	*161*	*162*	*163*	*164*	*165*	*166*	*167*	*168*
SiO2	54.72	54.31	54.72	54.80	53.95	51.54	51.34	52.60	53.28	53.42	52.92	52.15
TiO2	0.22	0.26	0.18	0.21	0.25	0.38	0.39	0.29	0.25	0.28	0.30	0.26
Al2O3	0.71	0.71	0.65	0.72	0.91	2.51	2.34	1.59	1.17	1.19	1.34	1.56
Cr2O3	0.37	0.27	0.27	0.24	0.28	0.09	0.06	0.03	0.10	0.04	0.07	0.03
Fe2O3	1.23	1.70	1.83	0.87	2.19	4.07	4.10	3.04	2.83	3.18	3.22	3.15
FeO	2.51	2.13	2.04	2.98	2.17	5.40	5.59	4.50	3.66	3.60	3.96	4.91
MnO	0.12	0.10	0.13	0.09	0.10	0.28	0.25	0.22	0.18	0.16	0.21	0.25
MgO	18.01	17.86	18.06	17.77	17.42	13.46	13.32	14.94	15.82	16.07	15.53	14.62
CaO	23.19	23.37	23.48	23.29	23.25	22.28	22.37	22.66	22.97	22.89	22.71	22.35
Na2O	0.24	0.24	0.23	0.23	0.33	0.78	0.74	0.57	0.51	0.49	0.53	0.57
K20	0.02	0.03	0.02	0.02	0.03	0.04	0.02	0.03	0.03	0.03	0.04	0.04
Total	101.33	100.97	101.62	101.23	100.87	100.82	100.52	100.48	100.81	101.36	100.83	99.88
					Cations Based on 6 Oxygens							
Si	1.966	1.960	1.961	1.972	1.952	1.906	1.907	1.936	1.946	1.941	1.937	1.935
Ti	0.006	0.007	0.005	0.006	0.007	0.011	0.011	0.008	0.007	0.008	0.008	0.007
Al	0.030	0.030	0.027	0.030	0.039	0.109	0.103	0.069	0.051	0.051	0.058	0.068
Cr	0.010	0.008	0.008	0.007	0.008	0.002	0.002	0.001	0.003	0.001	0.002	0.001
Fe3	0.033	0.046	0.049	0.024	0.060	0.113	0.115	0.084	0.078	0.087	0.089	0.088
Fe2	0.075	0.064	0.061	0.090	0.066	0.167	0.174	0.139	0.112	0.110	0.121	0.152
Mn	0.004	0.003	0.004	0.003	0.003	0.009	0.008	0.007	0.006	0.005	0.007	0.008
Mg	0.965	0.960	0.965	0.953	0.940	0.742	0.738	0.820	0.861	0.870	0.847	0.809
Ca	0.893	0.904	0.902	0.898	0.901	0.883	0.890	0.894	0.899	0.891	0.891	0.889
Na	0.017	0.017	0.016	0.016	0.023	0.056	0.053	0.041	0.036	0.035	0.038	0.041
K	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.002	0.002
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.679	3.679	3.688	3.670	3.623	3.097	3.103	3.327	3.443	3.434	3.382	3.294
mg	89.9	89.7	89.7	89.4	88.2	72.6	71.9	78.6	82.0	81.6	80.1	77.1
FEO*	3.61	3.66	3.69	3.77	4.14	9.06	9.28	7.24	6.20	6.47	6.86	7.74
Wo	45.4	45.8	45.6	45.7	45.8	46.3	46.5	46.2	46.1	45.5	45.7	45.9
En	49.1	48.6	48.8	48.5	47.8	38.9	38.5	42.3	44.2	44.4	43.5	41.7
Fs	5.5	5.6	5.6	5.8	6.4	14.7	15.0	11.5	9.7	10.0	10.8	12.4

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	169	*170*	*171*	*172*	*173*	*174*	*175*	*176*	*177*	*178*	*179*	*180*
SiO2	52.57	52.47	53.19	53.75	51.55	53.05	52.66	53.64	53.86	54.37	53.73	53.84
TiO2	0.36	0.34	0.29	0.22	0.48	0.26	0.28	0.24	0.23	0.22	0.25	0.17
Al2O3	1.50	1.39	1.01	1.04	1.75	1.49	1.56	1.09	0.97	0.95	1.14	0.96
Cr2O3	0.03	0.03	0.02	0.04	0.01	0.02	0.04	0.02	0.02	0.06	0.10	0.01
Fe2O3	3.09	3.11	1.69	1.72	3.28	1.90	3.31	1.89	1.79	1.99	1.65	2.11
FeO	5.40	5.77	7.88	5.18	9.52	7.30	6.45	6.07	4.98	4.24	5.10	4.09
MnO	0.23	0.27	0.24	0.18	0.32	0.27	0.33	0.21	0.19	0.19	0.17	0.15
MgO	14.46	14.51	13.90	15.50	11.82	13.87	13.61	15.36	15.86	16.60	16.11	16.38
CaO	22.45	22.17	22.29	22.78	21.59	22.13	22.43	22.09	22.70	22.81	22.04	22.77
Na2O	0.63	0.57	0.51	0.49	0.75	0.65	0.73	0.51	0.43	0.42	0.47	0.40
K20	0.03	0.03	0.02	0.01	0.00	0.01	0.02	0.01	0.02	0.00	0.01	0.02
Total	100.76	100.65	101.04	100.91	101.08	100.96	101.41	101.12	101.05	101.84	100.76	100.92
					Cations Based on 6 Oxygens							
Si	1.937	1.938	1.965	1.965	1.929	1.957	1.938	1.962	1.964	1.961	1.962	1.960
Ti	0.010	0.010	0.008	0.006	0.013	0.007	0.008	0.007	0.006	0.006	0.007	0.005
Al	0.065	0.060	0.044	0.045	0.077	0.065	0.068	0.047	0.042	0.040	0.049	0.041
Cr	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.000	0.000	0.002	0.003	0.000
Fe3	0.086	0.086	0.047	0.047	0.092	0.053	0.092	0.052	0.049	0.054	0.045	0.058
Fe2	0.167	0.178	0.243	0.158	0.298	0.225	0.198	0.186	0.152	0.128	0.156	0.124
Mn	0.007	0.008	0.007	0.006	0.010	0.008	0.010	0.006	0.006	0.006	0.005	0.005
Mg	0.794	0.799	0.765	0.844	0.659	0.762	0.747	0.837	0.862	0.893	0.877	0.889
Ca	0.887	0.877	0.882	0.892	0.866	0.875	0.885	0.866	0.887	0.881	0.862	0.888
Na	0.045	0.041	0.037	0.035	0.055	0.046	0.052	0.036	0.031	0.030	0.033	0.028
K	0.001	0.002	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.000	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.263	3.254	3.239	3.420	2.931	3.204	3.167	3.347	3.442	3.489	3.421	3.493
mg	75.9	75.1	72.5	80.4	62.8	73.3	72.0	77.9	81.1	83.1	81.3	83.0
FEO*	8.19	8.57	9.40	6.73	12.47	9.02	9.42	7.77	6.59	6.03	6.59	5.99
Wo	45.9	45.2	45.5	45.9	45.2	45.7	46.0	44.6	45.5	45.1	44.4	45.3
En	41.1	41.2	39.5	43.5	34.4	39.8	38.9	43.2	44.2	45.6	45.2	45.4
Fs	13.1	13.6	15.0	10.6	20.4	14.5	15.1	12.2	10.3	9.3	10.4	9.3

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	181	*182*	*183*	*184*	*185*	*186*	*187*	*188*	*189*	*190*	*191*	*192*
SiO2	53.79	52.31	51.52	53.53	52.91	51.59	52.33	54.82	54.80	54.93	54.41	54.31
TiO2	0.28	0.33	0.40	0.24	0.32	0.38	0.32	0.19	0.21	0.24	0.18	0.22
Al2O3	1.07	2.51	3.08	1.53	1.83	2.58	2.21	0.56	0.66	0.65	0.66	0.64
Cr2O3	0.06	0.03	0.07	0.15	0.06	0.04	0.05	0.22	0.11	0.26	0.08	0.02
Fe2O3	2.84	3.85	4.48	1.30	2.90	4.28	3.44	1.72	1.86	1.50	2.22	2.13
FeO	3.54	6.28	6.52	5.01	4.89	7.48	5.88	2.33	2.88	2.48	2.50	2.90
MnO	0.18	0.29	0.33	0.21	0.22	0.30	0.26	0.08	0.11	0.13	0.13	0.15
MgO	16.44	13.35	12.48	16.08	15.37	12.83	14.95	18.32	18.25	18.21	18.14	18.01
CaO	23.15	22.10	21.92	22.31	22.43	21.91	21.22	23.18	22.79	23.25	22.79	22.57
Na2O	0.40	0.89	1.02	0.38	0.49	0.71	0.61	0.20	0.20	0.22	0.21	0.22
K20	0.02	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.02	0.00	0.03	0.02
Total	101.75	101.95	101.83	100.73	101.42	102.10	101.28	101.62	101.90	101.88	101.33	101.18
					Cations Based on 6 Oxygens							
Si	1.945	1.915	1.896	1.954	1.929	1.899	1.917	1.964	1.961	1.964	1.958	1.959
Ti	0.008	0.009	0.011	0.007	0.009	0.011	0.009	0.005	0.006	0.006	0.005	0.006
Al	0.046	0.108	0.134	0.066	0.079	0.112	0.095	0.024	0.028	0.027	0.028	0.027
Cr	0.002	0.001	0.002	0.004	0.002	0.001	0.001	0.006	0.003	0.007	0.002	0.000
Fe3	0.077	0.106	0.124	0.036	0.080	0.119	0.095	0.046	0.050	0.040	0.060	0.058
Fe2	0.107	0.192	0.201	0.153	0.149	0.230	0.180	0.070	0.086	0.074	0.075	0.087
Mn	0.006	0.009	0.010	0.006	0.007	0.009	0.008	0.002	0.003	0.004	0.004	0.005
Mg	0.886	0.728	0.684	0.875	0.835	0.704	0.817	0.979	0.974	0.970	0.973	0.968
Ca	0.896	0.867	0.864	0.873	0.876	0.864	0.833	0.890	0.874	0.891	0.879	0.872
Na	0.028	0.063	0.073	0.027	0.034	0.050	0.043	0.014	0.014	0.016	0.015	0.016
K	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.480	3.051	2.924	3.422	3.307	2.967	3.163	3.692	3.640	3.677	3.644	3.619
mg	82.8	70.9	67.8	82.3	78.5	66.9	74.8	89.4	87.7	89.4	87.8	86.9
FEO*	6.09	9.75	10.55	6.17	7.50	11.33	8.98	3.88	4.56	3.83	4.49	4.82
Wo	45.6	45.8	46.1	45.1	45.2	45.1	43.3	44.8	44.0	45.1	44.2	43.9
En	45.1	38.5	36.5	45.2	43.1	36.7	42.4	49.3	49.1	49.1	49.0	48.8
Fs	9.4	15.8	17.3	9.7	11.8	18.2	14.3	5.9	6.9	5.8	6.8	7.3

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	193	*194*	*195*	*196*	*197*	*198*	*199*	*200*	*201*	*202*	*203*	*204*
SiO2	54.40	54.06	54.25	54.39	54.07	54.32	54.16	53.63	54.45	54.24	53.95	53.32
TiO2	0.27	0.24	0.23	0.20	0.24	0.22	0.18	0.21	0.19	0.23	0.24	0.24
Al2O3	0.72	0.69	0.65	0.60	0.77	0.66	0.74	0.70	0.76	0.83	0.90	1.16
Cr2O3	0.00	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe2O3	0.72	1.77	1.71	2.25	2.20	2.89	2.24	1.96	2.48	1.47	2.24	3.10
FeO	4.40	3.65	3.67	3.26	3.91	2.90	3.92	4.51	4.67	5.84	5.27	5.55
MnO	0.14	0.15	0.14	0.18	0.16	0.17	0.18	0.19	0.22	0.25	0.25	0.23
MgO	17.62	17.78	17.56	18.02	17.33	17.90	17.40	17.11	17.14	16.45	16.53	15.95
CaO	22.21	22.17	22.45	22.31	22.19	22.58	22.06	21.65	22.04	21.85	21.72	21.70
Na2O	0.18	0.19	0.25	0.22	0.30	0.26	0.31	0.29	0.34	0.34	0.40	0.40
K20	0.02	0.03	0.01	0.02	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.03
Total	100.68	100.72	100.95	101.44	101.20	101.91	101.21	100.26	102.30	101.50	101.52	101.68
Cations Based on 6 Oxygens												
Si	1.974	1.962	1.965	1.960	1.958	1.950	1.961	1.963	1.957	1.969	1.958	1.941
Ti	0.007	0.007	0.006	0.005	0.007	0.006	0.005	0.006	0.005	0.006	0.007	0.006
Al	0.031	0.029	0.028	0.025	0.033	0.028	0.031	0.030	0.032	0.035	0.039	0.050
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe3	0.020	0.048	0.047	0.061	0.060	0.078	0.061	0.054	0.067	0.040	0.061	0.085
Fe2	0.134	0.111	0.111	0.098	0.118	0.087	0.119	0.138	0.140	0.177	0.160	0.169
Mn	0.004	0.004	0.004	0.006	0.005	0.005	0.005	0.006	0.007	0.008	0.008	0.007
Mg	0.953	0.962	0.948	0.968	0.936	0.958	0.939	0.933	0.918	0.890	0.894	0.866
Ca	0.864	0.862	0.872	0.861	0.861	0.869	0.856	0.849	0.849	0.850	0.845	0.846
Na	0.012	0.014	0.018	0.015	0.021	0.018	0.022	0.020	0.024	0.024	0.028	0.028
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.588	3.587	3.586	3.596	3.529	3.579	3.530	3.507	3.468	3.429	3.412	3.331
mg	86.1	85.8	85.7	85.9	84.0	85.3	83.9	82.9	81.6	80.4	80.2	77.3
FEO*	5.06	5.24	5.21	5.28	5.89	5.50	5.94	6.28	6.90	7.16	7.29	8.34
Wo	43.8	43.5	44.1	43.3	43.6	43.6	43.3	43.0	43.0	43.4	43.1	43.0
En	48.4	48.5	47.9	48.7	47.4	48.1	47.6	47.3	46.5	45.5	45.6	44.0
Fs	7.8	8.0	8.0	8.0	9.0	8.3	9.1	9.7	10.5	11.1	11.3	12.9

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	205	*206*	*207*	*208*	*209*	*210*	*211*	*212*	*213*	*214*	*215*	*216*
SiO2	53.85	54.52	54.83	54.66	54.73	54.85	54.54	54.46	52.96	53.99	54.26	46.15
TiO2	0.22	0.25	0.19	0.21	0.16	0.19	0.28	0.27	0.35	0.44	0.41	0.43
Al2O3	1.11	1.03	0.66	0.71	0.68	0.70	0.78	0.75	0.81	0.89	0.93	0.91
Cr2O3	0.06	0.03	0.18	0.19	0.16	0.30	0.34	0.34	0.28	0.19	0.22	0.15
Fe2O3	2.63	1.57	1.90	1.78	2.01	1.46	1.39	1.75	3.22	2.36	1.79	12.43
FeO	4.26	5.51	2.79	3.24	2.57	2.83	3.25	2.96	2.04	3.00	3.73	-6.15
MnO	0.20	0.22	0.15	0.17	0.17	0.14	0.12	0.14	0.16	0.17	0.16	0.13
MgO	17.02	17.72	18.65	18.50	18.39	18.04	17.80	17.60	16.99	17.35	17.09	14.47
CaO	21.70	20.67	22.00	21.97	22.39	22.90	22.89	23.29	23.37	23.14	23.21	27.01
Na2O	0.42	0.34	0.27	0.21	0.29	0.27	0.22	0.22	0.25	0.26	0.24	0.25
K20	0.01	0.02	0.03	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01
Total	101.47	101.86	101.64	101.64	101.56	101.68	101.61	101.77	100.44	101.79	102.04	95.78
Cations Based on 6 Oxygens												
Si	1.949	1.962	1.963	1.960	1.962	1.966	1.960	1.956	1.934	1.944	1.951	1.792
Ti	0.006	0.007	0.005	0.006	0.004	0.005	0.007	0.007	0.010	0.012	0.011	0.013
Al	0.047	0.044	0.028	0.030	0.029	0.030	0.033	0.032	0.035	0.038	0.039	0.042
Cr	0.002	0.001	0.005	0.005	0.005	0.008	0.010	0.010	0.008	0.005	0.006	0.004
Fe3	0.072	0.042	0.051	0.048	0.054	0.039	0.038	0.047	0.088	0.064	0.048	0.363
Fe2	0.129	0.166	0.084	0.097	0.077	0.085	0.098	0.089	0.062	0.090	0.112	-0.200
Mn	0.006	0.007	0.004	0.005	0.005	0.004	0.003	0.004	0.005	0.005	0.005	0.004
Mg	0.918	0.951	0.996	0.989	0.983	0.964	0.954	0.942	0.925	0.931	0.916	0.838
Ca	0.841	0.797	0.844	0.844	0.860	0.880	0.881	0.896	0.915	0.892	0.894	1.124
Na	0.029	0.024	0.019	0.014	0.020	0.019	0.015	0.015	0.017	0.018	0.017	0.019
K	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.442	3.434	3.633	3.613	3.637	3.648	3.622	3.624	3.590	3.564	3.549	3.629
mg	82.1	82.0	88.1	87.2	88.2	88.6	87.6	87.4	86.0	85.8	85.1	83.7
FEO*	6.63	6.92	4.50	4.84	4.39	4.14	4.50	4.53	4.94	5.12	5.34	5.03
Wo	42.9	40.7	42.8	42.7	43.6	44.7	44.7	45.4	45.9	45.1	45.4	52.9
En	46.8	48.6	50.4	50.0	49.8	49.0	48.4	47.7	46.5	47.1	46.5	39.4
Fs	10.2	10.6	6.8	7.3	6.7	6.3	6.9	6.9	7.6	7.8	8.1	7.7

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1a (cont.)

OC 7-1 Clinopyroxene Line Scan Traverse

	217	*218*	*219*	*220*	*221*	*222*	*223*	*224*	*225*
SiO2	52.97	52.99	53.07	52.88	53.14	52.73	50.00	59.94	43.24
TiO2	0.45	0.57	0.67	0.69	0.61	0.71	0.54	0.29	0.02
Al2O3	1.16	1.37	1.40	1.54	1.25	1.50	2.47	19.71	13.46
Cr2O3	0.12	0.10	0.05	0.00	0.02	0.01	0.02	0.00	0.00
Fe2O3	3.36	1.91	3.36	2.88	2.45	2.79	6.38	-27.01	2.23
FeO	2.98	5.41	3.84	4.33	4.80	4.67	2.70	25.29	3.57
MnO	0.17	0.14	0.19	0.20	0.20	0.20	0.30	0.01	0.15
MgO	16.38	16.18	16.21	15.86	15.70	15.45	12.30	0.62	22.78
CaO	23.38	21.85	23.05	22.97	22.94	23.06	23.14	0.25	0.69
Na2O	0.29	0.30	0.32	0.32	0.32	0.31	0.95	3.05	0.40
K20	0.03	0.03	0.04	0.04	0.08	0.10	0.41	10.18	1.53
Total	101.28	100.84	102.18	101.70	101.51	101.54	99.21	92.33	88.07
					Cations Based on 6 Oxygens				
Si	1.926	1.938	1.918	1.921	1.936	1.923	1.884	2.298	1.707
Ti	0.012	0.016	0.018	0.019	0.017	0.019	0.015	0.008	0.001
Al	0.050	0.059	0.060	0.066	0.054	0.064	0.110	0.891	0.626
Cr	0.003	0.003	0.001	0.000	0.001	0.000	0.001	0.000	0.000
Fe3	0.092	0.053	0.091	0.079	0.067	0.077	0.181	-0.779	0.066
Fe2	0.091	0.166	0.116	0.132	0.146	0.142	0.085	0.811	0.118
Mn	0.005	0.004	0.006	0.006	0.006	0.006	0.009	0.000	0.005
Mg	0.888	0.882	0.873	0.859	0.852	0.840	0.691	0.035	1.341
Ca	0.911	0.856	0.892	0.894	0.895	0.901	0.934	0.010	0.029
Na	0.021	0.022	0.023	0.023	0.023	0.022	0.070	0.227	0.031
K	0.001	0.001	0.002	0.002	0.003	0.004	0.020	0.498	0.077
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.485	3.376	3.397	3.373	3.390	3.355	3.086	1.114	2.242
mg	83.0	80.2	80.8	80.3	80.0	79.3	72.2	52.9	87.9
FEO*	6.00	7.13	6.86	6.92	7.00	7.18	8.44	0.98	5.58
Wo	46.0	43.8	45.2	45.5	45.7	46.0	49.4	13.3	1.9
En	44.8	45.1	44.3	43.7	43.5	42.9	36.5	45.8	86.3
Fs	9.2	11.2	10.5	10.7	10.9	11.2	14.1	40.9	11.9

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1b

OC8-16 Clinopyroxene Phenocryst Compositions

	CORE 1,1	*RIM 1,2*	*RIM 2,1*	*RIM 2,2*	*CORE 3,1*	*RIM 3,2*	*CORE 4,1*	*RIM 4,2*	*CORE 5,1*	*CORE 5,2*	*CORE 5,3*	*CORE 5,4*
SiO2	54.44	54.07	54.34	53.11	54.01	53.63	53.18	52.94	52.50	51.26	51.10	52.78
TiO2	0.19	0.26	0.19	0.41	0.22	0.23	0.25	0.35	0.26	0.33	0.36	0.27
Al2O3	0.57	0.76	0.59	1.20	0.66	0.96	1.03	0.72	1.94	2.63	2.98	1.49
Cr2O3	0.16	0.10	0.12	0.27	0.11	0.47	0.04	0.10	0.15	0.06	0.09	0.12
Fe2O3	0.82	1.91	1.29	2.23	1.71	1.41	1.60	3.66	1.72	4.27	3.03	2.55
FeO	3.24	2.41	2.77	2.90	3.16	2.57	5.09	1.47	3.94	5.48	6.35	4.26
MnO	0.13	0.11	0.18	0.15	0.13	0.09	0.21	0.10	0.15	0.35	0.29	0.17
MgO	18.15	17.86	18.31	16.62	18.38	17.50	16.29	17.38	15.87	13.14	12.69	15.61
CaO	22.24	22.88	22.20	23.10	21.59	22.73	21.73	23.46	21.26	21.95	21.71	22.26
Na2O	0.23	0.26	0.24	0.34	0.22	0.28	0.35	0.21	0.64	0.92	0.94	0.56
K20	0.00	0.00	0.01	0.01	0.02	0.02	0.00	0.00	0.13	0.00	0.00	0.01
Total	100.17	100.62	100.24	100.34	100.20	99.88	99.77	100.39	98.56	100.39	99.54	100.09
Cations Based on 6 Oxygens												
Si	1.977	1.958	1.971	1.940	1.963	1.958	1.961	1.931	1.950	1.905	1.914	1.943
Ti	0.005	0.007	0.005	0.011	0.006	0.006	0.007	0.010	0.007	0.009	0.010	0.007
Al	0.024	0.032	0.025	0.052	0.028	0.041	0.045	0.031	0.085	0.115	0.132	0.065
Cr	0.004	0.003	0.003	0.008	0.003	0.013	0.001	0.003	0.004	0.002	0.003	0.003
Fe3	0.022	0.052	0.035	0.061	0.047	0.039	0.044	0.100	0.048	0.119	0.085	0.071
Fe2	0.099	0.073	0.084	0.089	0.096	0.078	0.157	0.045	0.122	0.170	0.199	0.131
Mn	0.004	0.003	0.005	0.005	0.004	0.003	0.007	0.003	0.005	0.011	0.009	0.005
Mg	0.982	0.964	0.990	0.905	0.996	0.952	0.895	0.945	0.879	0.728	0.709	0.856
Ca	0.865	0.888	0.863	0.904	0.841	0.889	0.858	0.917	0.846	0.874	0.871	0.878
Na	0.016	0.019	0.017	0.024	0.015	0.020	0.025	0.015	0.046	0.066	0.068	0.040
K	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.006	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.665	3.642	3.668	3.534	3.620	3.637	3.443	3.623	3.379	3.049	3.015	3.382
mg	89.0	88.5	89.3	85.8	87.5	89.1	81.6	86.7	83.7	71.5	71.4	80.9
FEO*	3.98	4.13	3.93	4.91	4.69	3.83	6.53	4.76	5.49	9.32	9.08	6.56
Wo	43.9	44.9	43.8	46.1	42.5	45.4	43.9	45.7	44.6	46.2	46.7	45.3
En	49.9	48.8	50.2	46.2	50.3	48.6	45.8	47.1	46.4	38.5	38.0	44.2
Fs	6.1	6.3	6.0	7.7	7.2	6.0	10.3	7.2	9.0	15.3	15.3	10.4

Table B.1b (cont.)

OC8-16 Clinopyroxene Phenocryst Compositions

	CORE 6,1	*RIM 6,2*	*CORE 7,1*	*RIM 7,2*	*RIM(2) 7,3*	*CORE 8,1*	*RIM 8,2*	*CORE 9,1*	*RIM 9,2*	*CORE 10,1*	*RIM(1) 10,2*	*RIM(2) 10,3*
SiO2	52.24	53.61	53.01	54.50	52.89	54.29	53.49	53.82	54.00	50.65	50.81	53.72
TiO2	0.77	0.24	0.21	0.21	0.45	0.23	0.45	0.04	0.26	0.48	0.46	0.23
Al2O3	1.94	0.97	1.23	0.63	1.26	0.66	1.25	0.98	0.91	2.22	2.30	0.83
Cr2O3	0.03	0.05	0.05	0.04	0.10	0.04	0.39	0.00	0.27	0.00	0.07	0.12
Fe2O3	1.70	2.28	2.71	1.49	2.38	1.88	1.89	2.65	2.17	4.57	4.22	1.39
FeO	3.98	3.02	4.14	2.94	4.95	3.28	2.88	3.42	2.10	5.30	5.58	2.56
MnO	0.08	0.12	0.19	0.14	0.27	0.12	0.10	0.36	0.10	0.33	0.28	0.09
MgO	15.82	17.36	15.69	18.25	15.17	18.05	16.94	16.51	17.80	13.09	13.16	17.58
CaO	22.85	22.18	22.42	22.34	22.27	21.99	23.10	21.84	22.94	22.58	22.13	22.94
Na2O	0.35	0.39	0.53	0.23	0.57	0.29	0.33	0.69	0.32	0.67	0.76	0.23
K20	0.01	0.00	0.03	0.01	0.06	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Total	99.77	100.23	100.21	100.78	100.37	100.83	100.84	100.31	100.87	99.89	99.76	99.69
Cations Based on 6 Oxygens												
Si	1.925	1.954	1.949	1.969	1.948	1.964	1.942	1.966	1.951	1.897	1.903	1.963
Ti	0.021	0.007	0.006	0.006	0.012	0.006	0.012	0.001	0.007	0.014	0.013	0.006
Al	0.084	0.042	0.053	0.027	0.055	0.028	0.053	0.042	0.039	0.098	0.102	0.036
Cr	0.001	0.002	0.001	0.001	0.003	0.001	0.011	0.000	0.008	0.000	0.002	0.003
Fe3	0.047	0.063	0.075	0.040	0.066	0.051	0.052	0.073	0.059	0.129	0.119	0.038
Fe2	0.123	0.092	0.127	0.089	0.152	0.099	0.087	0.104	0.063	0.166	0.175	0.078
Mn	0.002	0.004	0.006	0.004	0.008	0.004	0.003	0.011	0.003	0.010	0.009	0.003
Mg	0.869	0.943	0.860	0.983	0.833	0.973	0.917	0.899	0.959	0.731	0.735	0.958
Ca	0.902	0.866	0.883	0.864	0.879	0.852	0.899	0.855	0.888	0.906	0.888	0.898
Na	0.025	0.028	0.038	0.016	0.041	0.021	0.023	0.049	0.022	0.049	0.055	0.016
K	0.000	0.000	0.001	0.000	0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.408	3.549	3.409	3.647	3.347	3.597	3.552	3.460	3.630	3.102	3.087	3.656
mg	83.6	85.9	80.9	88.4	79.2	86.6	86.8	83.5	88.7	71.3	71.5	89.2
FEO*	5.51	5.08	6.58	4.28	7.09	4.97	4.58	5.80	4.05	9.41	9.37	3.81
Wo	46.5	44.1	45.4	43.7	45.5	43.1	46.0	44.3	45.1	46.9	46.4	45.5
En	44.8	48.0	44.2	49.7	43.1	49.3	46.9	46.6	48.7	37.8	38.3	48.6
Fs	8.8	7.9	10.4	6.5	11.3	7.6	7.1	9.2	6.2	15.3	15.3	5.9

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1b (cont.)

OC8-16 Clinopyroxene Phenocryst Compositions

	RIM(3) ***10,4***	***GCORE*** ***11,1***	***RIM*** ***11,2***	***GCORE*** ***12,1***	***RIM*** ***12,2***
SiO2	52.83	54.06	52.92	49.55	53.63
TiO2	0.40	0.24	0.37	0.75	0.23
Al2O3	1.11	0.83	1.32	4.03	1.23
Cr2O3	0.20	0.20	0.43	0.05	0.24
Fe2O3	2.48	0.13	0.92	3.96	0.80
FeO	2.66	3.84	4.01	7.09	3.70
MnO	0.09	0.10	0.13	0.28	0.12
MgO	16.76	17.35	16.26	11.13	16.68
CaO	22.99	22.29	22.46	21.70	22.82
Na2O	0.31	0.29	0.36	1.04	0.33
K20	0.01	0.03	0.01	0.03	0.02
Total	99.84	99.37	99.17	99.61	99.80
					Cations Based on 6 Oxygens
Si	1.939	1.982	1.955	1.871	1.964
Ti	0.011	0.007	0.010	0.021	0.006
Al	0.048	0.036	0.057	0.179	0.053
Cr	0.006	0.006	0.013	0.002	0.007
Fe3	0.068	0.004	0.025	0.113	0.022
Fe2	0.082	0.118	0.124	0.224	0.113
Mn	0.003	0.003	0.004	0.009	0.004
Mg	0.917	0.948	0.896	0.626	0.911
Ca	0.904	0.876	0.889	0.878	0.896
Na	0.022	0.020	0.026	0.076	0.023
K	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000
DS	3.553	3.625	3.514	2.781	3.562
mg	85.9	88.7	85.7	65.0	87.1
FEO*	4.89	3.96	4.83	10.66	4.42
Wo	45.9	45.0	46.0	47.7	46.1
En	46.5	48.7	46.3	34.0	46.9
Fs	7.6	6.2	7.7	18.3	7.0

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1b

OC 8-16 Clinopyroxene Line Scan Traverse

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
SiO2	50.32	52.21	52.93	52.77	53.55	53.76	53.27	53.23	53.51	53.84	53.41	53.91
TiO2	0.96	0.53	0.34	0.30	0.27	0.18	0.15	0.15	0.21	0.16	0.24	0.24
Al2O3	2.67	1.66	1.05	1.10	1.02	0.78	0.70	0.70	0.71	0.75	1.08	1.08
Cr2O3	0.03	0.43	0.01	0.22	0.29	0.29	0.22	0.20	0.19	0.24	0.01	0.05
Fe2O3	3.00	0.98	0.91	1.02	0.18	-0.04	0.66	0.62	0.48	-0.37	0.99	0.58
FeO	5.62	4.66	4.44	4.03	4.10	3.86	3.09	3.24	3.24	4.02	3.71	4.14
MnO	0.20	0.14	0.17	0.13	0.09	0.10	0.09	0.11	0.09	0.09	0.11	0.12
MgO	13.83	15.70	16.02	16.17	16.72	17.20	17.14	17.04	17.21	17.15	16.79	17.00
CaO	21.86	22.09	22.60	22.71	22.51	22.26	22.57	22.49	22.39	22.34	22.32	22.21
Na2O	0.51	0.36	0.29	0.26	0.30	0.27	0.25	0.25	0.30	0.25	0.36	0.34
K20	0.07	0.04	0.04	0.02	0.02	0.01	0.02	0.03	0.02	0.03	0.02	0.02
Total	99.06	98.79	98.79	98.73	99.04	98.68	98.15	98.06	98.36	98.48	99.05	99.68
Cations Based on 6 Oxygens												
Si	1.891	1.943	1.966	1.960	1.975	1.984	1.977	1.978	1.981	1.990	1.969	1.974
Ti	0.027	0.015	0.010	0.008	0.007	0.005	0.004	0.004	0.006	0.004	0.007	0.006
Al	0.118	0.073	0.046	0.048	0.044	0.034	0.030	0.031	0.031	0.032	0.047	0.047
Cr	0.001	0.013	0.000	0.007	0.008	0.009	0.006	0.006	0.006	0.007	0.000	0.001
Fe3	0.085	0.028	0.025	0.028	0.005	-0.001	0.019	0.017	0.013	-0.010	0.028	0.016
Fe2	0.177	0.145	0.138	0.125	0.126	0.119	0.096	0.101	0.100	0.124	0.114	0.127
Mn	0.006	0.004	0.005	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004
Mg	0.775	0.871	0.887	0.895	0.919	0.946	0.948	0.944	0.950	0.945	0.923	0.928
Ca	0.880	0.881	0.900	0.904	0.889	0.881	0.898	0.896	0.888	0.885	0.882	0.872
Na	0.037	0.026	0.021	0.019	0.021	0.020	0.018	0.018	0.022	0.018	0.025	0.024
K	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.119	3.425	3.515	3.541	3.586	3.640	3.666	3.655	3.653	3.653	3.558	3.556
mg	74.8	83.4	84.4	85.3	87.5	88.9	89.2	88.9	89.3	89.2	86.7	86.7
FEO*	8.32	5.55	5.26	4.95	4.27	3.82	3.69	3.80	3.67	3.69	4.61	4.66
Wo	45.9	45.8	46.1	46.3	45.8	45.3	45.8	45.7	45.5	45.5	45.3	44.9
En	40.4	45.3	45.5	45.8	47.4	48.7	48.4	48.2	48.7	48.6	47.4	47.8
Fs	13.6	9.0	8.4	7.9	6.8	6.1	5.8	6.0	5.8	5.9	7.3	7.3

Table B.1b (cont.)

OC 8-16 Clinopyroxene Line Scan Traverse

	13	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*
SiO2	54.02	53.77	53.65	54.06	53.75	53.93	53.81	53.59	53.39	52.84	52.79	53.38
TiO2	0.22	0.24	0.19	0.21	0.29	0.27	0.21	0.21	0.25	0.31	0.35	0.21
Al2O3	0.90	0.89	1.04	0.98	1.02	0.96	0.94	1.16	1.39	1.69	1.56	1.10
Cr2O3	0.08	0.02	0.11	0.11	0.14	0.37	0.22	0.11	0.05	0.03	0.04	0.18
Fe2O3	0.59	0.87	0.77	0.39	0.96	0.01	1.37	1.53	1.21	1.85	1.96	1.20
FeO	3.82	3.65	3.82	3.67	3.42	3.73	2.64	3.55	4.12	4.75	3.95	3.32
MnO	0.09	0.11	0.13	0.10	0.09	0.09	0.11	0.15	0.15	0.17	0.18	0.10
MgO	17.31	17.30	16.99	17.38	17.34	17.37	17.05	16.62	16.21	15.67	16.12	16.98
CaO	22.26	22.36	22.19	22.35	22.33	22.28	23.23	22.92	22.60	22.23	22.28	22.40
Na2O	0.31	0.26	0.34	0.29	0.31	0.29	0.33	0.33	0.41	0.45	0.42	0.33
K20	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.03
Total	99.62	99.48	99.25	99.57	99.66	99.31	99.93	100.18	99.80	100.00	99.68	99.23
Cations Based on 6 Oxygens												
Si	1.977	1.972	1.973	1.977	1.966	1.977	1.965	1.959	1.960	1.945	1.944	1.964
Ti	0.006	0.007	0.005	0.006	0.008	0.007	0.006	0.006	0.007	0.008	0.010	0.006
Al	0.039	0.038	0.045	0.042	0.044	0.041	0.040	0.050	0.060	0.073	0.068	0.048
Cr	0.002	0.001	0.003	0.003	0.004	0.011	0.006	0.003	0.001	0.001	0.001	0.005
Fe3	0.016	0.024	0.021	0.011	0.026	0.000	0.038	0.042	0.034	0.051	0.054	0.033
Fe2	0.117	0.112	0.117	0.112	0.105	0.114	0.081	0.109	0.127	0.146	0.122	0.102
Mn	0.003	0.003	0.004	0.003	0.003	0.003	0.003	0.004	0.005	0.005	0.005	0.003
Mg	0.944	0.946	0.931	0.948	0.946	0.949	0.928	0.906	0.887	0.860	0.885	0.931
Ca	0.873	0.879	0.874	0.876	0.875	0.875	0.909	0.898	0.889	0.877	0.879	0.883
Na	0.022	0.019	0.024	0.021	0.022	0.020	0.024	0.024	0.029	0.032	0.030	0.024
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.598	3.601	3.570	3.612	3.592	3.626	3.627	3.543	3.487	3.381	3.436	3.577
mg	87.7	87.4	87.0	88.5	87.8	89.2	88.7	85.7	84.7	81.3	83.4	87.3
FEO*	4.35	4.43	4.51	4.02	4.28	3.74	3.88	4.93	5.21	6.41	5.72	4.40
Wo	44.8	44.8	45.0	45.0	44.8	45.1	46.5	45.9	45.9	45.3	45.3	45.3
En	48.4	48.3	47.9	48.7	48.4	48.9	47.5	46.4	45.8	44.5	45.6	47.8
Fs	6.8	6.9	7.1	6.3	6.7	5.9	6.1	7.7	8.3	10.2	9.1	6.9

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1b (cont.)

OC 8-16 Clinopyroxene Line Scan Traverse

	25	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*
SiO2	53.72	51.67	53.33	52.79	52.39	52.83	52.79	52.92	52.68	53.33	52.52	52.23
TiO2	0.23	0.25	0.20	0.23	0.23	0.19	0.18	0.19	0.19	0.22	0.28	0.29
Al2O3	1.11	1.37	1.26	1.24	1.09	0.92	0.91	0.93	0.99	0.96	1.33	1.59
Cr2O3	0.21	0.01	0.08	0.13	0.10	0.49	0.50	0.52	0.49	0.29	0.17	0.15
Fe2O3	0.47	1.25	1.44	-0.13	0.55	1.01	0.51	0.04	0.57	-1.45	-0.01	-0.06
FeO	3.88	4.76	5.01	6.46	5.55	3.40	3.79	4.03	3.96	5.91	5.65	6.02
MnO	0.11	0.13	0.18	0.16	0.17	0.12	0.09	0.12	0.09	0.11	0.17	0.16
MgO	16.83	14.94	15.40	14.40	14.71	16.06	15.76	15.81	15.62	15.14	14.67	14.40
CaO	22.67	22.40	22.46	22.47	22.69	22.80	22.92	22.78	22.91	22.81	22.32	22.30
Na2O	0.29	0.37	0.53	0.47	0.38	0.41	0.41	0.40	0.40	0.36	0.53	0.48
K20	0.03	0.01	0.01	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.02
Total	99.54	97.18	99.90	98.25	97.89	98.24	97.89	97.76	97.92	97.69	97.65	97.58
Cations Based on 6 Oxygens												
Si	1.971	1.958	1.966	1.984	1.974	1.969	1.975	1.981	1.973	2.002	1.980	1.973
Ti	0.006	0.007	0.006	0.006	0.007	0.005	0.005	0.005	0.005	0.006	0.008	0.008
Al	0.048	0.061	0.055	0.055	0.049	0.040	0.040	0.041	0.043	0.042	0.059	0.071
Cr	0.006	0.000	0.002	0.004	0.003	0.014	0.015	0.015	0.015	0.009	0.005	0.004
Fe3	0.013	0.036	0.040	-0.004	0.016	0.028	0.014	0.001	0.016	-0.041	0.000	-0.002
Fe2	0.119	0.151	0.154	0.203	0.175	0.106	0.119	0.126	0.124	0.186	0.178	0.190
Mn	0.003	0.004	0.006	0.005	0.005	0.004	0.003	0.004	0.003	0.003	0.006	0.005
Mg	0.920	0.844	0.846	0.807	0.826	0.892	0.879	0.883	0.872	0.848	0.824	0.811
Ca	0.891	0.910	0.887	0.905	0.916	0.911	0.919	0.914	0.919	0.918	0.901	0.903
Na	0.020	0.028	0.038	0.034	0.028	0.030	0.029	0.029	0.029	0.026	0.038	0.035
K	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.582	3.437	3.414	3.398	3.446	3.581	3.582	3.587	3.562	3.541	3.421	3.383
mg	87.5	81.9	81.3	80.2	81.3	86.9	86.9	87.4	86.1	85.4	82.2	81.1
FEO*	4.30	5.88	6.31	6.34	6.05	4.31	4.25	4.07	4.48	4.61	5.65	5.97
Wo	45.9	46.9	46.0	47.4	47.4	47.0	47.6	47.5	47.6	48.0	47.4	47.4
En	47.4	43.5	43.9	42.2	42.7	46.1	45.5	45.9	45.1	44.4	43.3	42.6
Fs	6.8	9.6	10.1	10.4	9.9	6.9	6.9	6.6	7.3	7.6	9.3	9.9

Table B.1b (cont.)

OC 8-16 Clinopyroxene Line Scan Traverse

	37	*38*	*39*	*40*	*41*	*42*	*43*	*44*	*45*	*46*	*47*	*48*
SiO2	51.41	50.40	50.60	50.53	51.04	51.25	47.01	49.24	49.87	49.53	50.12	50.48
TiO2	0.43	0.44	0.34	0.44	0.36	0.36	0.76	0.78	0.54	0.90	0.51	0.53
Al2O3	2.77	3.56	3.34	3.15	2.41	2.36	4.43	4.63	3.23	6.26	3.44	3.56
Cr2O3	0.08	0.08	0.12	0.05	0.09	0.05	0.04	0.05	0.01	0.02	0.05	0.04
Fe2O3	1.23	3.53	3.95	3.85	2.99	3.56	1.66	3.91	4.07	-6.11	3.78	3.97
FeO	7.38	6.44	5.97	6.68	6.32	5.68	8.92	7.19	6.20	16.48	7.31	7.50
MnO	0.25	0.26	0.29	0.31	0.24	0.26	0.25	0.31	0.28	0.28	0.29	0.33
MgO	12.36	12.22	12.33	12.17	13.06	13.64	11.29	11.03	12.06	8.57	11.34	11.22
CaO	22.05	21.53	21.57	21.65	22.49	22.39	18.15	21.40	22.45	17.09	21.49	21.52
Na2O	0.84	0.96	1.04	0.94	0.56	0.56	0.91	1.04	0.71	1.13	1.07	1.15
K20	0.02	0.05	0.03	0.02	0.03	0.03	0.05	0.06	0.04	0.28	0.03	0.03
Total	98.80	99.47	99.60	99.77	99.59	100.13	93.46	99.63	99.46	94.42	99.43	100.32
Cations Based on 6 Oxygens												
Si	1.939	1.894	1.898	1.897	1.914	1.908	1.883	1.858	1.882	1.968	1.894	1.893
Ti	0.012	0.012	0.010	0.012	0.010	0.010	0.023	0.022	0.015	0.027	0.015	0.015
Al	0.123	0.157	0.148	0.139	0.107	0.103	0.209	0.206	0.144	0.293	0.153	0.157
Cr	0.002	0.002	0.004	0.001	0.003	0.002	0.001	0.001	0.000	0.001	0.001	0.001
Fe3	0.035	0.100	0.111	0.109	0.084	0.100	0.050	0.111	0.116	-0.183	0.108	0.112
Fe2	0.233	0.202	0.187	0.210	0.198	0.177	0.299	0.227	0.196	0.548	0.231	0.235
Mn	0.008	0.008	0.009	0.010	0.008	0.008	0.008	0.010	0.009	0.009	0.009	0.010
Mg	0.695	0.684	0.689	0.681	0.730	0.757	0.674	0.620	0.678	0.508	0.639	0.627
Ca	0.891	0.867	0.867	0.871	0.904	0.893	0.779	0.865	0.907	0.728	0.870	0.864
Na	0.061	0.070	0.076	0.068	0.041	0.040	0.071	0.076	0.052	0.087	0.079	0.084
K	0.001	0.002	0.001	0.001	0.001	0.001	0.002	0.003	0.002	0.014	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.064	2.921	2.943	2.930	3.125	3.148	2.689	2.717	2.965	2.386	2.835	2.798
mg	72.2	69.4	69.8	68.1	72.1	73.2	65.9	64.7	68.5	58.2	65.3	64.4
FEO*	8.49	9.62	9.53	10.14	9.01	8.88	10.41	10.71	9.87	10.98	10.72	11.07
Wo	48.1	46.8	46.7	46.6	47.2	46.4	43.2	47.4	47.8	45.5	47.1	47.0
En	37.5	36.9	37.2	36.4	38.1	39.3	37.4	34.0	35.8	31.7	34.6	34.1
Fs	14.4	16.3	16.1	17.0	14.7	14.4	19.4	18.5	16.4	22.8	18.3	18.9

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1b (cont.)

OC 8-16 Clinopyroxene Line Scan Traverse

	49	*50*	*51*	*52*	*53*	*54*	*55*	*56*	*57*	*58*	*59*	*60*
SiO2	49.59	50.33	51.87	53.19	53.96	53.67	53.20	52.87	53.11	53.18	53.19	50.03
TiO2	0.63	0.56	0.35	0.27	0.15	0.17	0.19	0.23	0.22	0.28	0.20	0.22
Al2O3	4.12	4.08	2.34	1.49	0.89	0.93	0.96	1.16	1.22	1.29	1.13	1.21
Cr2O3	0.05	0.03	0.06	0.14	0.18	0.25	0.35	0.23	0.14	0.11	0.10	0.10
Fe2O3	3.64	3.03	1.64	0.69	0.64	-0.17	0.65	1.16	2.87	1.71	2.37	6.96
FeO	7.57	8.01	6.76	5.62	4.24	5.03	4.99	5.19	3.91	4.96	4.27	-0.25
MnO	0.29	0.31	0.26	0.20	0.17	0.16	0.16	0.20	0.19	0.21	0.19	0.20
MgO	10.88	11.08	13.30	15.09	16.38	15.73	15.40	14.89	15.74	15.44	15.56	14.82
CaO	21.36	21.56	22.03	22.22	22.79	22.90	22.76	22.69	22.74	22.54	22.80	24.49
Na2O	1.11	1.06	0.71	0.55	0.39	0.37	0.42	0.51	0.51	0.49	0.50	0.47
K20	0.03	0.02	0.03	0.04	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.02
Total	99.27	100.07	99.36	99.48	99.81	99.04	99.12	99.15	100.66	100.22	100.32	98.27
Cations Based on 6 Oxygens												
Si	1.879	1.890	1.941	1.969	1.979	1.987	1.975	1.967	1.944	1.956	1.954	1.885
Ti	0.018	0.016	0.010	0.007	0.004	0.005	0.005	0.006	0.006	0.008	0.006	0.006
Al	0.184	0.181	0.103	0.065	0.039	0.041	0.042	0.051	0.053	0.056	0.049	0.054
Cr	0.001	0.001	0.002	0.004	0.005	0.007	0.010	0.007	0.004	0.003	0.003	0.003
Fe3	0.104	0.085	0.046	0.019	0.018	-0.005	0.018	0.033	0.079	0.047	0.066	0.197
Fe2	0.240	0.252	0.212	0.174	0.130	0.156	0.155	0.161	0.120	0.153	0.131	-0.008
Mn	0.009	0.010	0.008	0.006	0.005	0.005	0.005	0.006	0.006	0.007	0.006	0.006
Mg	0.614	0.620	0.742	0.833	0.896	0.868	0.852	0.826	0.859	0.847	0.852	0.832
Ca	0.867	0.868	0.883	0.881	0.896	0.909	0.905	0.905	0.892	0.888	0.897	0.988
Na	0.081	0.077	0.051	0.039	0.027	0.027	0.030	0.037	0.036	0.035	0.036	0.035
K	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.000	0.000	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	2.749	2.777	3.149	3.381	3.558	3.542	3.492	3.419	3.422	3.403	3.432	3.475
mg	64.1	64.8	74.2	81.2	85.8	85.2	83.1	81.0	81.2	80.9	81.2	81.4
FEO*	10.85	10.74	8.24	6.24	4.82	4.87	5.58	6.24	6.49	6.50	6.41	6.02
Wo	47.5	47.5	46.9	46.2	46.2	47.1	46.9	47.0	45.8	45.9	46.1	49.2
En	33.7	34.0	39.4	43.7	46.2	45.0	44.1	42.9	44.1	43.8	43.8	41.4
Fs	18.8	18.5	13.7	10.1	7.6	7.8	9.0	10.1	10.2	10.3	10.1	9.4

Table B.1b (cont.)

OC 8-16 Clinopyroxene Line Scan Traverse

	61	*62*	*63*	*64*	*65*	*66*	*67*	*68*	*69*	*70*	*71*	*72*
SiO2	53.31	52.50	53.87	54.16	53.81	52.95	52.18	52.62	53.17	53.70	53.84	53.76
TiO2	0.23	0.34	0.29	0.25	0.26	0.46	0.42	0.36	0.33	0.21	0.24	0.25
Al2O3	1.26	1.26	1.06	0.91	1.04	1.77	1.99	1.75	1.41	1.06	0.87	0.87
Cr2O3	0.07	0.17	0.14	0.25	0.12	0.04	0.02	0.01	0.09	0.08	0.24	0.38
Fe2O3	2.16	1.25	1.29	1.34	1.73	2.36	2.25	2.27	1.74	1.68	1.63	1.35
FeO	4.27	4.10	3.41	3.02	3.00	4.19	5.06	4.88	3.84	3.41	2.32	2.39
MnO	0.18	0.16	0.10	0.09	0.13	0.14	0.16	0.16	0.12	0.12	0.10	0.07
MgO	15.63	15.95	17.15	17.60	17.27	16.09	15.23	15.46	16.45	16.99	17.73	17.73
CaO	22.65	22.63	22.83	22.81	22.94	22.32	21.85	22.12	22.38	22.70	22.88	22.73
Na2O	0.55	0.29	0.27	0.26	0.27	0.44	0.50	0.49	0.39	0.30	0.26	0.26
K20	0.02	0.02	0.03	0.03	0.01	0.02	0.03	0.02	0.03	0.03	0.01	0.05
Total	100.34	98.66	100.42	100.71	100.58	100.78	99.68	100.14	99.95	100.27	100.12	99.84
Cations Based on 6 Oxygens												
Si	1.956	1.954	1.960	1.962	1.955	1.933	1.932	1.938	1.950	1.959	1.959	1.960
Ti	0.006	0.009	0.008	0.007	0.007	0.013	0.012	0.010	0.009	0.006	0.007	0.007
Al	0.055	0.055	0.045	0.039	0.045	0.076	0.087	0.076	0.061	0.046	0.037	0.037
Cr	0.002	0.005	0.004	0.007	0.003	0.001	0.001	0.000	0.002	0.002	0.007	0.011
Fe3	0.060	0.035	0.035	0.036	0.047	0.065	0.063	0.063	0.048	0.046	0.045	0.037
Fe2	0.131	0.128	0.104	0.092	0.091	0.128	0.157	0.150	0.118	0.104	0.071	0.073
Mn	0.006	0.005	0.003	0.003	0.004	0.004	0.005	0.005	0.004	0.004	0.003	0.002
Mg	0.855	0.885	0.930	0.950	0.935	0.875	0.841	0.849	0.899	0.924	0.961	0.964
Ca	0.890	0.902	0.890	0.885	0.893	0.873	0.867	0.873	0.880	0.887	0.892	0.888
Na	0.039	0.021	0.019	0.018	0.019	0.031	0.036	0.035	0.028	0.022	0.018	0.018
K	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.002
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.423	3.503	3.580	3.621	3.588	3.383	3.299	3.339	3.478	3.560	3.652	3.660
mg	81.7	84.5	87.0	88.1	87.1	82.0	79.3	79.9	84.4	86.0	89.3	89.8
FEO*	6.22	5.22	4.57	4.23	4.56	6.32	7.08	6.92	5.41	4.91	3.78	3.61
Wo	46.0	46.3	45.4	45.1	45.4	45.0	45.0	45.1	45.2	45.2	45.3	45.3
En	44.1	45.4	47.5	48.4	47.6	45.1	43.6	43.9	46.2	47.1	48.8	49.1
Fs	9.9	8.3	7.1	6.5	7.0	9.9	11.4	11.0	8.5	7.6	5.9	5.6

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1b (cont.)

OC 8-16 Clinopyroxene Line Scan Traverse

	73	*74*	*75*	*76*	*77*	*78*	*79*	*80*	*81*	*82*	*83*	*84*
SiO2	53.70	53.65	55.23	53.49	53.97	54.32	53.71	53.62	53.98	53.85	53.44	51.80
TiO2	0.25	0.30	0.28	0.24	0.20	0.20	0.16	0.26	0.19	0.25	0.25	0.40
Al2O3	0.94	0.97	0.92	0.82	0.81	0.77	0.75	0.91	0.72	0.82	0.95	1.28
Cr2O3	0.15	0.21	0.07	0.06	0.02	0.07	0.06	0.10	0.18	0.26	0.29	0.50
Fe2O3	1.72	1.42	-0.55	2.24	0.43	0.69	1.07	1.28	0.71	0.37	1.07	3.62
FeO	2.74	2.94	4.82	2.19	4.03	3.66	3.14	3.17	3.23	3.88	3.15	1.52
MnO	0.09	0.11	0.10	0.10	0.16	0.14	0.12	0.14	0.13	0.13	0.12	0.14
MgO	17.62	17.49	17.51	17.57	16.96	17.22	17.05	17.16	17.24	16.93	16.83	15.89
CaO	22.37	22.65	22.44	22.82	22.62	22.90	23.02	22.77	22.94	22.77	22.98	23.94
Na2O	0.31	0.24	0.28	0.26	0.28	0.26	0.25	0.26	0.26	0.26	0.29	0.34
K20	0.03	0.02	0.03	0.04	0.01	0.03	0.03	0.02	0.02	0.02	0.03	0.03
Total	99.93	99.99	101.13	99.82	99.49	100.26	99.35	99.67	99.59	99.54	99.40	99.45
						Cations Based on 6 Oxygens						
Si	1.959	1.957	1.990	1.954	1.981	1.977	1.973	1.964	1.976	1.976	1.964	1.916
Ti	0.007	0.008	0.008	0.007	0.006	0.005	0.004	0.007	0.005	0.007	0.007	0.011
Al	0.040	0.042	0.039	0.035	0.035	0.033	0.032	0.039	0.031	0.035	0.041	0.056
Cr	0.004	0.006	0.002	0.002	0.000	0.002	0.002	0.003	0.005	0.008	0.008	0.014
Fe3	0.047	0.039	-0.015	0.061	0.012	0.019	0.030	0.035	0.019	0.010	0.030	0.101
Fe2	0.084	0.090	0.145	0.067	0.124	0.112	0.096	0.097	0.099	0.119	0.097	0.047
Mn	0.003	0.003	0.003	0.003	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Mg	0.958	0.951	0.940	0.957	0.928	0.934	0.934	0.937	0.941	0.926	0.922	0.876
Ca	0.874	0.886	0.866	0.893	0.889	0.893	0.906	0.894	0.900	0.895	0.905	0.949
Na	0.022	0.017	0.020	0.018	0.020	0.018	0.018	0.018	0.018	0.019	0.020	0.024
K	0.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.607	3.613	3.594	3.633	3.602	3.621	3.640	3.607	3.652	3.614	3.610	3.542
mg	88.0	88.1	87.8	88.2	87.2	87.8	88.1	87.6	88.8	87.8	87.9	85.6
FEO*	4.29	4.22	4.33	4.20	4.42	4.28	4.10	4.32	3.86	4.21	4.11	4.78
Wo	44.5	45.1	44.7	45.1	45.5	45.6	46.1	45.5	45.9	45.9	46.3	48.1
En	48.8	48.4	48.5	48.4	47.5	47.7	47.5	47.7	48.0	47.5	47.2	44.4
Fs	6.7	6.5	6.7	6.5	6.9	6.7	6.4	6.8	6.0	6.6	6.5	7.5

Table B.1b (cont.)

OC 8-16 Clinopyroxene Line Scan Traverse

	85	*86*	*87*	*88*	*89*	*90*	*91*	*92*
SiO2	53.46	50.60	52.25	47.57	48.66	37.66	49.66	51.10
TiO2	0.28	0.36	0.44	0.34	0.52	2.24	1.12	0.61
Al2O3	0.99	1.09	1.13	1.10	1.38	9.63	2.70	1.17
Cr2O3	0.31	0.05	0.02	0.33	0.22	0.05	0.12	0.10
Fe2O3	0.78	2.48	3.01	20.73	12.62	19.18	5.36	4.47
FeO	4.05	2.85	2.74	-8.70	-3.47	0.11	3.36	3.02
MnO	0.14	0.15	0.15	0.23	0.18	0.23	0.19	0.20
MgO	15.91	15.62	16.09	25.03	19.90	15.03	14.56	15.64
CaO	23.56	22.36	23.10	15.47	19.44	4.61	22.06	22.62
Na2O	0.28	0.26	0.32	0.24	0.26	0.67	0.35	0.27
K20	0.05	0.05	0.07	0.04	0.11	3.57	0.33	0.11
Total	99.79	95.87	99.30	102.39	99.83	92.98	99.80	99.29
					Cations Based on 6 Oxygens			
Si	1.967	1.939	1.934	1.694	1.790	1.527	1.853	1.905
Ti	0.008	0.010	0.012	0.009	0.014	0.068	0.031	0.017
Al	0.043	0.049	0.049	0.046	0.060	0.460	0.118	0.051
Cr	0.009	0.002	0.001	0.009	0.007	0.002	0.004	0.003
Fe3	0.022	0.072	0.084	0.556	0.350	0.585	0.150	0.126
Fe2	0.124	0.091	0.085	-0.259	-0.107	0.004	0.105	0.094
Mn	0.004	0.005	0.005	0.007	0.006	0.008	0.006	0.006
Mg	0.873	0.892	0.888	1.329	1.091	0.908	0.810	0.869
Ca	0.929	0.918	0.916	0.590	0.766	0.200	0.882	0.904
Na	0.020	0.019	0.023	0.017	0.019	0.053	0.025	0.019
K	0.002	0.002	0.003	0.002	0.005	0.185	0.016	0.005
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.563	3.526	3.506	3.405	3.412	1.534	3.151	3.403
mg	85.7	84.6	84.0	81.8	81.8	60.7	76.0	79.8
FEO*	4.75	5.09	5.44	9.95	7.89	17.37	8.18	7.05
Wo	47.7	46.5	46.5	26.6	36.5	11.8	45.3	45.3
En	44.8	45.2	45.0	60.0	52.0	53.5	41.6	43.6
Fs	7.5	8.3	8.5	13.4	11.6	34.7	13.1	11.0

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1c

DAT4-5 Clinopyroxene Compositions

	CORE 1,1	*RIM 1,2*	*CORE 2,1*	*RIM 2,2*	*CORE 3,1*	*RIM 3,2*
SiO2	53.24	53.03	55.44	52.93	54.78	54.01
TiO2	0.34	0.18	0.20	0.21	0.20	0.18
Al2O3	1.46	0.68	0.45	0.56	0.43	0.55
Cr2O3	0.01	0.01	0.08	0.04	0.03	0.06
Fe2O3	3.79	2.51	0.54	4.76	2.32	3.50
FeO	1.69	2.08	3.57	0.49	2.13	1.22
MnO	0.11	0.07	0.11	0.12	0.14	0.14
MgO	17.24	17.14	18.17	17.55	18.27	17.85
CaO	23.17	23.05	23.01	23.65	23.24	23.56
Na2O	0.38	0.26	0.20	0.27	0.23	0.30
K20	0.00	0.04	0.00	0.00	0.00	0.00
Total	101.43	99.05	101.77	100.59	101.76	101.37
					Cations Based on 6 Oxygens	
Si	1.921	1.955	1.984	1.926	1.962	1.945
Ti	0.009	0.005	0.005	0.006	0.005	0.005
Al	0.062	0.029	0.019	0.024	0.018	0.023
Cr	0.000	0.000	0.002	0.001	0.001	0.002
Fe3	0.103	0.070	0.015	0.131	0.062	0.095
Fe2	0.051	0.064	0.107	0.015	0.064	0.037
Mn	0.003	0.002	0.003	0.004	0.004	0.004
Mg	0.927	0.942	0.969	0.952	0.975	0.958
Ca	0.896	0.911	0.882	0.922	0.892	0.909
Na	0.027	0.019	0.014	0.019	0.016	0.021
K	0.000	0.002	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.520	3.641	3.678	3.643	3.679	3.659
mg	85.8	87.6	88.9	86.7	88.6	87.9
FEO*	5.10	4.34	4.06	4.78	4.21	4.37
Wo	45.3	45.8	44.7	45.7	44.7	45.5
En	46.9	47.4	49.1	47.1	48.9	47.9
Fs	7.8	6.7	6.2	7.2	6.3	6.6

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1d

OC8-6 Clinopyroxene Compositions

	CORE 1,1	*RIM 1,2*	*RIM 1,3*	*CORE 15,1*	*RIM 15,2*	*CORE 20,1*	*CORE 20,2*	*RIM 20,3*	*CORE 2,1*	*RIM 2,2*	*CORE 2,3*	*CORE 3,1*
SiO2	54.42	54.70	55.33	54.73	54.80	54.95	54.35	54.64	54.18	54.93	54.03	54.13
TiO2	0.34	0.13	0.20	0.19	0.16	0.18	0.17	0.20	0.26	0.23	0.24	0.24
Al2O3	1.01	0.64	0.58	0.64	0.66	0.54	0.58	0.62	0.72	0.57	0.71	0.65
Cr2O3	0.06	0.03	0.00	0.02	0.01	0.05	0.04	0.00	0.01	0.06	0.02	0.03
Fe2O3	0.94	0.87	0.00	0.87	1.13	1.16	1.91	1.14	1.66	0.07	1.34	1.74
FeO	4.65	4.75	4.76	5.28	4.27	4.53	3.89	5.24	6.64	4.20	6.72	4.22
MnO	0.21	0.18	0.16	0.23	0.18	0.21	0.18	0.17	0.26	0.19	0.29	0.20
MgO	16.73	16.84	17.47	16.34	17.05	17.30	17.42	16.64	16.27	17.78	15.76	16.89
CaO	22.32	22.35	22.73	22.63	22.64	22.25	22.02	21.83	21.31	22.20	21.71	22.24
Na2O	0.45	0.42	0.23	0.43	0.40	0.38	0.39	0.52	0.39	0.28	0.41	0.42
K20	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.02	0.00	0.01	0.00	0.00
Total	101.13	100.91	101.47	101.36	101.31	101.55	100.95	101.02	101.71	100.52	101.22	100.75
Cations Based on 6 Oxygens												
Si	1.972	1.985	1.992	1.984	1.980	1.981	1.970	1.985	1.968	1.990	1.974	1.970
Ti	0.009	0.003	0.005	0.005	0.004	0.005	0.004	0.005	0.007	0.006	0.006	0.007
Al	0.043	0.028	0.025	0.027	0.028	0.023	0.025	0.027	0.031	0.024	0.031	0.028
Cr	0.002	0.001	0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.002	0.001	0.001
Fe3	0.026	0.024	0.000	0.024	0.031	0.031	0.052	0.031	0.045	0.002	0.037	0.048
Fe2	0.141	0.144	0.143	0.160	0.129	0.137	0.118	0.159	0.202	0.127	0.205	0.128
Mn	0.006	0.006	0.005	0.007	0.005	0.006	0.005	0.005	0.008	0.006	0.009	0.006
Mg	0.903	0.911	0.938	0.883	0.918	0.930	0.941	0.901	0.881	0.960	0.858	0.916
Ca	0.866	0.869	0.876	0.879	0.876	0.859	0.855	0.850	0.830	0.862	0.850	0.867
Na	0.032	0.030	0.016	0.030	0.028	0.027	0.027	0.037	0.028	0.020	0.029	0.030
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.493	3.539	3.610	3.500	3.558	3.552	3.552	3.480	3.371	3.628	3.376	3.522
mg	84.4	84.4	86.7	82.8	85.2	84.7	84.7	82.6	78.1	88.1	78.0	83.9
FEO*	5.50	5.53	4.76	6.06	5.29	5.57	5.61	6.27	8.14	4.26	7.92	5.78
Wo	44.7	44.6	44.8	45.2	44.9	43.9	43.5	43.8	42.4	44.2	43.6	44.3
En	46.7	46.8	47.9	45.4	47.0	47.5	47.9	46.4	45.0	49.2	44.0	46.8
Fs	8.6	8.6	7.3	9.4	8.2	8.6	8.6	9.8	12.6	6.6	12.4	9.0

Table B.1d (cont.)

OC8-6 Clinopyroxene Compositions

	RIM 3,2	*CORE 4,1*	*RIM 4,2*	*CORE 18,1*	*CORE 18,2*	*RIM 18,3*	*GCORE 5,1*	*RIM 5,1*	*CORE 7,1*	*RIM 7,2*
SiO2	54.47	54.78	54.99	55.57	54.89	54.74	53.13	54.52	54.06	54.25
TiO2	0.19	0.16	0.20	0.11	0.23	0.18	0.40	0.18	0.12	0.23
Al2O3	0.65	0.59	0.55	0.44	0.73	0.74	1.20	0.48	0.43	0.92
Cr2O3	0.08	0.09	0.11	0.06	0.01	0.01	0.03	0.07	0.08	0.00
Fe2O3	1.01	0.68	1.09	0.10	1.54	0.96	2.42	0.19	1.04	0.65
FeO	4.29	5.16	4.58	5.32	4.62	4.78	5.72	3.67	2.95	5.01
MnO	0.17	0.17	0.18	0.24	0.19	0.15	0.23	0.12	0.13	0.16
MgO	16.97	16.44	16.98	16.51	17.24	16.99	15.33	17.40	17.65	16.60
CaO	22.46	22.15	22.43	22.82	22.25	22.23	22.01	22.83	22.71	22.33
Na2O	0.39	0.56	0.46	0.45	0.38	0.39	0.52	0.27	0.23	0.37
K20	0.01	0.02	0.01	0.07	0.38	0.03	0.01	0.01	0.02	0.01
Total	100.69	100.80	101.58	101.69	102.45	101.20	100.99	99.73	99.42	100.53
Cations Based on 6 Oxygens										
Si	1.980	1.992	1.983	2.003	1.971	1.981	1.948	1.991	1.980	1.978
Ti	0.005	0.004	0.005	0.003	0.006	0.005	0.011	0.005	0.003	0.006
Al	0.028	0.025	0.023	0.019	0.031	0.031	0.052	0.021	0.019	0.040
Cr	0.002	0.003	0.003	0.002	0.000	0.000	0.001	0.002	0.002	0.000
Fe3	0.028	0.019	0.030	0.003	0.042	0.026	0.067	0.005	0.029	0.018
Fe2	0.130	0.157	0.138	0.160	0.139	0.144	0.176	0.112	0.090	0.153
Mn	0.005	0.005	0.005	0.007	0.006	0.005	0.007	0.004	0.004	0.005
Mg	0.919	0.891	0.913	0.887	0.923	0.916	0.838	0.947	0.964	0.902
Ca	0.875	0.863	0.866	0.881	0.856	0.862	0.865	0.894	0.891	0.872
Na	0.027	0.039	0.032	0.032	0.027	0.028	0.037	0.019	0.016	0.026
K	0.000	0.001	0.001	0.003	0.000	0.001	0.000	0.000	0.001	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.561	3.505	3.540	3.550	3.512	3.528	3.321	3.669	3.686	3.510
mg	85.3	83.5	84.5	84.5	83.7	84.3	77.6	89.0	89.0	84.1
FEO*	5.20	5.77	5.56	5.41	6.00	5.64	7.90	3.84	3.89	5.60
Wo	44.8	44.7	44.5	45.6	43.7	44.2	44.5	45.6	45.1	44.8
En	47.1	46.2	46.9	45.9	47.1	47.0	43.1	48.4	48.8	46.4
Fs	8.1	9.1	8.6	8.4	9.2	8.8	12.5	6.0	6.0	8.8

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1d

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	226	*227*	*228*	*229*	*230*	*231*	*232*	*233*	*234*	*235*	*236*	*237*
SiO2	55.52	54.57	53.97	54.71	54.30	54.52	54.59	54.18	54.07	54.38	54.20	54.18
TiO2	0.08	0.06	0.20	0.19	0.21	0.16	0.15	0.20	0.16	0.16	0.13	0.16
Al2O3	0.67	0.49	0.68	0.64	0.66	0.56	0.46	0.62	0.55	0.49	0.50	0.48
Cr2O3	0.01	0.04	0.03	0.03	0.02	0.02	0.02	0.04	0.04	0.08	0.02	0.02
Fe2O3	1.93	1.68	1.19	1.23	2.44	2.23	2.59	3.09	2.26	2.28	2.05	2.18
FeO	3.23	3.60	4.64	4.65	3.56	3.11	1.56	2.19	2.60	1.81	2.20	2.20
MnO	0.16	0.17	0.19	0.19	0.21	0.13	0.10	0.13	0.12	0.08	0.12	0.11
MgO	16.66	15.77	16.52	16.82	17.25	17.23	18.19	17.50	17.38	18.07	17.94	17.88
CaO	23.18	23.48	22.39	22.62	22.51	23.24	23.62	23.31	23.26	23.34	23.08	23.21
Na2O	0.71	0.68	0.35	0.35	0.35	0.33	0.22	0.33	0.27	0.23	0.21	0.21
K20	0.13	0.07	0.05	0.04	0.04	0.03	0.02	0.02	0.02	0.03	0.02	0.02
Total	102.27	100.60	100.20	101.47	101.55	101.57	101.52	101.59	100.71	100.95	100.46	100.62
Cations Based on 6 Oxygens												
Si	1.985	1.990	1.977	1.978	1.960	1.965	1.959	1.951	1.962	1.962	1.966	1.963
Ti	0.002	0.002	0.005	0.005	0.006	0.004	0.004	0.006	0.004	0.004	0.003	0.004
Al	0.028	0.021	0.029	0.027	0.028	0.024	0.020	0.026	0.024	0.021	0.021	0.021
Cr	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.002	0.000	0.000
Fe3	0.052	0.046	0.033	0.034	0.066	0.061	0.070	0.084	0.062	0.062	0.056	0.059
Fe2	0.097	0.110	0.142	0.141	0.108	0.094	0.047	0.066	0.079	0.055	0.067	0.067
Mn	0.005	0.005	0.006	0.006	0.006	0.004	0.003	0.004	0.004	0.002	0.004	0.003
Mg	0.888	0.857	0.902	0.906	0.928	0.926	0.973	0.939	0.940	0.972	0.970	0.966
Ca	0.888	0.917	0.879	0.876	0.871	0.897	0.908	0.899	0.904	0.902	0.897	0.901
Na	0.049	0.048	0.025	0.025	0.025	0.023	0.015	0.023	0.019	0.016	0.015	0.014
K	0.006	0.003	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.543	3.548	3.527	3.534	3.541	3.597	3.704	3.608	3.635	3.698	3.684	3.680
mg	85.7	84.6	83.7	83.9	84.2	85.7	89.3	86.2	87.0	89.3	88.8	88.4
FEO*	4.97	5.11	5.72	5.76	5.76	5.12	3.90	4.97	4.63	3.86	4.04	4.16
Wo	46.1	47.5	44.9	44.8	44.1	45.4	45.4	45.2	45.6	45.3	45.1	45.2
En	46.1	44.4	46.1	46.3	47.0	46.8	48.7	47.2	47.4	48.8	48.7	48.5
Fs	7.7	8.1	9.0	8.9	8.8	7.8	5.9	7.5	7.1	5.8	6.2	6.3

Table B.1d (cont.)

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	238	*239*	*240*	*241*	*242*	*243*	*244*	*245*	*246*	*247*	*248*	*249*
SiO2	54.19	53.63	53.62	53.71	53.14	53.40	53.32	53.38	53.37	53.51	53.11	53.60
TiO2	0.19	0.24	0.29	0.31	0.32	0.27	0.27	0.21	0.24	0.24	0.22	0.21
Al2O3	0.52	0.83	0.90	0.93	0.99	0.74	0.62	0.62	0.58	0.60	0.59	0.61
Cr2O3	0.02	0.05	0.02	0.02	0.02	0.03	0.00	0.01	0.03	0.00	0.00	0.01
Fe2O3	2.40	2.46	2.81	1.70	2.19	2.52	1.31	1.80	1.21	1.48	1.71	1.34
FeO	2.11	3.66	3.82	4.58	4.30	3.99	5.00	4.67	5.22	5.00	4.89	5.20
MnO	0.13	0.15	0.17	0.20	0.21	0.22	0.19	0.23	0.23	0.25	0.22	0.24
MgO	17.64	16.64	16.36	16.13	16.12	16.31	16.28	16.47	16.17	16.24	16.16	16.10
CaO	23.30	22.51	22.67	22.49	22.36	22.48	22.06	22.15	22.09	22.33	22.07	22.16
Na2O	0.30	0.42	0.45	0.44	0.41	0.43	0.31	0.29	0.30	0.29	0.31	0.37
K20	0.02	0.02	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.01
Total	100.81	100.60	101.16	100.53	100.05	100.39	99.38	99.84	99.47	99.94	99.31	99.83
Cations Based on 6 Oxygens												
Si	1.962	1.957	1.950	1.964	1.954	1.957	1.973	1.966	1.975	1.971	1.969	1.976
Ti	0.005	0.007	0.008	0.008	0.009	0.007	0.008	0.006	0.007	0.007	0.006	0.006
Al	0.022	0.035	0.039	0.040	0.043	0.032	0.027	0.027	0.025	0.026	0.026	0.027
Cr	0.000	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000
Fe3	0.065	0.067	0.077	0.047	0.061	0.069	0.036	0.050	0.034	0.041	0.048	0.037
Fe2	0.064	0.112	0.116	0.140	0.132	0.122	0.155	0.144	0.161	0.154	0.152	0.160
Mn	0.004	0.005	0.005	0.006	0.006	0.007	0.006	0.007	0.007	0.008	0.007	0.008
Mg	0.952	0.905	0.887	0.880	0.884	0.891	0.898	0.904	0.892	0.891	0.893	0.885
Ca	0.904	0.880	0.884	0.881	0.881	0.883	0.875	0.874	0.876	0.881	0.877	0.875
Na	0.021	0.030	0.032	0.031	0.029	0.030	0.023	0.021	0.022	0.021	0.022	0.027
K	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.657	3.507	3.467	3.466	3.457	3.483	3.501	3.505	3.497	3.500	3.492	3.483
mg	88.0	83.5	82.1	82.5	82.1	82.3	82.4	82.4	82.0	82.1	81.7	81.8
FEO*	4.27	5.87	6.35	6.11	6.27	6.26	6.18	6.29	6.31	6.33	6.44	6.40
Wo	45.5	44.8	45.0	45.2	45.0	44.9	44.5	44.3	44.6	44.8	44.5	44.7
En	48.0	46.1	45.2	45.2	45.1	45.3	45.7	45.9	45.4	45.3	45.4	45.2
Fs	6.5	9.1	9.8	9.6	9.8	9.8	9.7	9.8	9.9	9.9	10.1	10.1

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1d (cont.)

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	250	*251*	*252*	*253*	*254*	*255*	*256*	*257*	*258*	*259*	*260*	*261*
SiO2	53.06	54.06	53.88	53.83	53.77	53.66	53.66	53.95	53.68	53.50	53.92	53.99
TiO2	0.23	0.25	0.20	0.24	0.19	0.20	0.21	0.18	0.17	0.20	0.21	0.18
Al2O3	0.58	0.61	0.60	0.60	0.58	0.60	0.60	0.59	0.61	0.62	0.61	0.63
Cr2O3	0.00	0.01	0.03	0.01	0.00	0.04	0.00	0.04	0.02	0.02	0.00	0.00
Fe2O3	1.70	2.25	3.01	2.43	2.38	2.26	2.30	2.22	2.00	2.59	2.42	1.56
FeO	5.07	5.04	4.37	4.92	4.70	4.71	4.98	4.72	4.91	4.21	4.38	5.04
MnO	0.23	0.21	0.23	0.23	0.22	0.24	0.22	0.22	0.23	0.23	0.23	0.23
MgO	16.21	16.79	16.69	16.64	16.70	16.50	16.37	16.56	16.38	16.59	16.61	16.56
CaO	21.80	21.90	22.08	21.87	21.89	22.01	22.02	22.30	22.07	22.21	22.29	21.83
Na2O	0.32	0.34	0.40	0.37	0.36	0.37	0.36	0.34	0.35	0.34	0.38	0.42
K20	0.02	0.03	0.04	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.05	0.01
Total	99.21	101.48	101.52	101.14	100.81	100.61	100.76	101.13	100.43	100.53	101.08	100.44
Cations Based on 6 Oxygens												
Si	1.969	1.961	1.955	1.961	1.963	1.964	1.963	1.964	1.968	1.958	1.962	1.975
Ti	0.006	0.007	0.005	0.007	0.005	0.005	0.006	0.005	0.005	0.006	0.006	0.005
Al	0.025	0.026	0.026	0.026	0.025	0.026	0.026	0.025	0.026	0.027	0.026	0.027
Cr	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Fe3	0.048	0.061	0.082	0.067	0.065	0.062	0.063	0.061	0.055	0.071	0.066	0.043
Fe2	0.157	0.153	0.133	0.150	0.144	0.144	0.152	0.144	0.151	0.129	0.133	0.154
Mn	0.007	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Mg	0.896	0.908	0.903	0.903	0.909	0.900	0.893	0.899	0.895	0.905	0.901	0.903
Ca	0.867	0.851	0.859	0.853	0.856	0.863	0.863	0.870	0.867	0.871	0.869	0.856
Na	0.023	0.024	0.028	0.026	0.025	0.026	0.026	0.024	0.025	0.024	0.026	0.029
K	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.479	3.462	3.460	3.455	3.476	3.474	3.458	3.486	3.478	3.492	3.487	3.480
mg	81.4	80.9	80.8	80.7	81.3	81.3	80.5	81.5	81.3	81.9	81.9	82.1
FEO*	6.60	7.06	7.08	7.11	6.84	6.75	7.05	6.72	6.71	6.54	6.56	6.45
Wo	44.0	43.1	43.4	43.3	43.4	43.8	43.8	44.1	44.1	44.1	44.1	43.7
En	45.5	46.0	45.7	45.8	46.0	45.7	45.3	45.5	45.5	45.8	45.7	46.2
Fs	10.4	10.9	10.9	11.0	10.6	10.5	10.9	10.4	10.5	10.1	10.1	10.1

Table B.1d (cont.)

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	262	*263*	*264*	*265*	*266*	*267*	*268*	*269*	*270*	*271*	*272*	*273*
SiO2	54.02	54.48	54.47	54.71	54.67	54.57	54.54	54.72	54.48	54.34	54.17	54.36
TiO2	0.19	0.15	0.15	0.12	0.13	0.12	0.15	0.11	0.15	0.18	0.21	0.18
Al2O3	0.71	0.47	0.46	0.43	0.43	0.43	0.43	0.42	0.44	0.43	0.47	0.43
Cr2O3	0.06	0.00	0.00	0.00	0.07	0.03	0.02	0.06	0.08	0.09	0.07	0.04
Fe2O3	1.47	1.23	0.90	0.49	1.11	1.08	1.37	1.40	1.59	0.60	0.35	0.58
FeO	4.60	4.02	4.16	4.11	3.51	3.72	3.23	3.04	2.88	3.66	3.74	3.63
MnO	0.21	0.16	0.17	0.17	0.14	0.15	0.18	0.12	0.14	0.11	0.11	0.10
MgO	16.83	17.60	17.54	17.82	17.96	17.87	18.01	18.23	18.09	17.99	17.81	17.92
CaO	21.90	22.26	21.99	22.12	22.27	22.24	22.25	22.45	22.38	22.12	22.16	22.19
Na2O	0.40	0.25	0.32	0.23	0.27	0.23	0.27	0.23	0.28	0.20	0.21	0.23
K20	0.02	0.01	0.02	0.03	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.00
Total	100.38	100.63	100.16	100.23	100.57	100.48	100.46	100.78	100.52	99.73	99.30	99.66
Cations Based on 6 Oxygens												
Si	1.973	1.978	1.985	1.989	1.981	1.981	1.978	1.977	1.974	1.984	1.986	1.985
Ti	0.005	0.004	0.004	0.003	0.003	0.003	0.004	0.003	0.004	0.005	0.006	0.005
Al	0.030	0.020	0.020	0.018	0.018	0.018	0.018	0.018	0.019	0.018	0.020	0.019
Cr	0.002	0.000	0.000	0.000	0.002	0.001	0.000	0.002	0.002	0.003	0.002	0.001
Fe3	0.040	0.034	0.025	0.013	0.030	0.030	0.037	0.038	0.043	0.016	0.010	0.016
Fe2	0.141	0.122	0.127	0.125	0.106	0.113	0.098	0.092	0.087	0.112	0.115	0.111
Mn	0.006	0.005	0.005	0.005	0.004	0.005	0.006	0.004	0.004	0.003	0.003	0.003
Mg	0.916	0.952	0.953	0.966	0.970	0.967	0.974	0.982	0.977	0.979	0.973	0.976
Ca	0.857	0.866	0.859	0.862	0.865	0.865	0.865	0.869	0.869	0.865	0.871	0.868
Na	0.028	0.018	0.022	0.016	0.019	0.016	0.019	0.016	0.019	0.014	0.015	0.016
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.509	3.605	3.601	3.640	3.646	3.638	3.646	3.671	3.658	3.666	3.666	3.666
mg	83.5	86.0	86.3	87.5	87.7	87.2	87.8	88.3	88.2	88.4	88.7	88.5
FEO*	5.92	5.12	4.97	4.55	4.51	4.69	4.46	4.30	4.31	4.20	4.05	4.15
Wo	43.9	43.9	43.7	43.8	43.9	43.8	43.8	43.9	44.0	43.9	44.2	44.1
En	46.9	48.2	48.5	49.1	49.2	49.0	49.3	49.6	49.4	49.6	49.5	49.5
Fs	9.3	7.9	7.7	7.0	6.9	7.2	6.9	6.6	6.6	6.5	6.3	6.4

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1d (cont.)

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	274	*275*	*276*	*277*	*278*	*279*	*280*	*281*	*282*	*283*	*284*	*285*
SiO2	54.72	54.46	54.55	54.28	54.56	54.29	54.23	54.18	54.17	54.31	54.34	54.41
TiO2	0.18	0.16	0.16	0.23	0.18	0.17	0.21	0.12	0.17	0.17	0.15	0.13
Al2O3	0.42	0.42	0.45	0.47	0.48	0.44	0.48	0.49	0.48	0.49	0.51	0.46
Cr2O3	0.14	0.12	0.11	0.06	0.08	0.07	0.05	0.00	0.00	0.00	0.04	0.01
Fe2O3	0.58	0.75	0.72	0.03	0.68	0.66	0.79	1.04	0.29	0.65	0.04	-0.07
FeO	3.45	3.52	3.45	4.04	3.32	3.83	3.78	3.76	4.50	4.08	4.65	4.80
MnO	0.09	0.12	0.12	0.13	0.10	0.13	0.13	0.14	0.15	0.15	0.17	0.14
MgO	18.46	18.07	18.52	17.93	18.12	17.86	17.77	17.27	16.89	16.92	16.82	16.68
CaO	21.98	22.18	21.83	21.91	22.36	22.11	22.30	22.64	22.57	23.08	22.81	22.84
Na2O	0.21	0.22	0.18	0.20	0.22	0.20	0.19	0.24	0.25	0.23	0.22	0.25
K20	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.03	0.03	0.02	0.03	0.02
Total	100.22	100.01	100.08	99.27	100.09	99.77	99.92	99.90	99.50	100.11	99.77	99.67
Cations Based on 6 Oxygens												
Si	1.984	1.982	1.981	1.989	1.982	1.983	1.979	1.981	1.991	1.985	1.992	1.997
Ti	0.005	0.004	0.004	0.006	0.005	0.005	0.006	0.003	0.005	0.005	0.004	0.004
Al	0.018	0.018	0.019	0.020	0.020	0.019	0.020	0.021	0.021	0.021	0.022	0.020
Cr	0.004	0.003	0.003	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.001	0.000
Fe3	0.016	0.021	0.020	0.001	0.019	0.018	0.022	0.029	0.008	0.018	0.001	-0.002
Fe2	0.105	0.107	0.105	0.124	0.101	0.117	0.115	0.115	0.138	0.125	0.143	0.147
Mn	0.003	0.004	0.004	0.004	0.003	0.004	0.004	0.004	0.005	0.005	0.005	0.004
Mg	0.997	0.980	1.002	0.979	0.981	0.972	0.967	0.941	0.925	0.921	0.919	0.913
Ca	0.854	0.865	0.849	0.860	0.870	0.865	0.872	0.887	0.889	0.904	0.896	0.898
Na	0.015	0.015	0.013	0.014	0.016	0.014	0.013	0.017	0.018	0.016	0.015	0.018
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.683	3.668	3.677	3.661	3.679	3.651	3.645	3.629	3.613	3.625	3.618	3.616
mg	89.2	88.5	88.9	88.7	89.2	87.8	87.6	86.7	86.3	86.6	86.5	86.2
FEO*	3.97	4.20	4.10	4.07	3.93	4.43	4.49	4.70	4.76	4.67	4.69	4.75
Wo	43.3	43.8	43.0	43.8	44.2	43.9	44.1	45.0	45.3	45.9	45.7	45.9
En	50.6	49.7	50.7	49.9	49.8	49.3	48.9	47.7	47.2	46.8	46.9	46.7
Fs	6.1	6.5	6.3	6.3	6.1	6.9	6.9	7.3	7.5	7.3	7.3	7.4

Table B.1d (cont.)

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	286	*287*	*288*	*289*	*290*	*291*	*292*	*293*	*294*	*295*	*296*	*297*
SiO2	54.33	54.14	54.30	54.48	54.27	54.59	54.50	54.48	54.14	54.67	54.60	54.63
TiO2	0.19	0.15	0.17	0.14	0.14	0.19	0.15	0.17	0.20	0.17	0.14	0.12
Al2O3	0.50	0.49	0.49	0.50	0.48	0.49	0.48	0.49	0.49	0.47	0.55	0.56
Cr2O3	0.01	0.01	0.01	0.00	0.00	0.03	0.05	0.03	0.00	0.05	0.05	0.04
Fe2O3	0.41	0.71	-0.01	0.01	0.28	0.68	0.49	0.35	0.58	0.38	0.43	0.28
FeO	4.45	4.18	4.73	4.69	4.48	4.21	4.25	4.48	4.15	3.95	4.32	4.29
MnO	0.17	0.16	0.15	0.17	0.13	0.15	0.14	0.16	0.16	0.14	0.13	0.15
MgO	17.04	17.13	17.02	16.92	16.95	17.72	17.75	17.63	17.43	17.89	16.97	17.08
CaO	22.48	22.57	22.41	22.58	22.62	22.14	21.98	21.99	22.13	22.09	22.48	22.19
Na2O	0.28	0.22	0.23	0.27	0.26	0.24	0.23	0.22	0.25	0.25	0.41	0.44
K20	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.00	0.02
Total	99.88	99.78	99.51	99.78	99.61	100.44	100.04	99.99	99.53	100.08	100.09	99.79
Cations Based on 6 Oxygens												
Si	1.988	1.984	1.994	1.995	1.991	1.983	1.987	1.988	1.985	1.989	1.992	1.996
Ti	0.005	0.004	0.005	0.004	0.004	0.005	0.004	0.005	0.005	0.005	0.004	0.003
Al	0.022	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.020	0.024	0.024
Cr	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.002	0.001	0.001
Fe3	0.011	0.019	0.000	0.000	0.008	0.019	0.013	0.010	0.016	0.010	0.012	0.008
Fe2	0.136	0.128	0.145	0.144	0.137	0.128	0.129	0.137	0.127	0.120	0.132	0.131
Mn	0.005	0.005	0.005	0.005	0.004	0.005	0.004	0.005	0.005	0.004	0.004	0.005
Mg	0.930	0.936	0.932	0.924	0.927	0.960	0.965	0.959	0.953	0.970	0.923	0.931
Ca	0.881	0.886	0.882	0.886	0.889	0.862	0.858	0.860	0.870	0.861	0.879	0.869
Na	0.020	0.015	0.016	0.019	0.018	0.017	0.016	0.016	0.018	0.018	0.029	0.031
K	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.001	0.000	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.603	3.618	3.616	3.611	3.618	3.617	3.627	3.618	3.620	3.647	3.595	3.598
mg	86.3	86.4	86.5	86.5	86.5	86.8	87.1	86.8	86.9	88.1	86.5	87.0
FEO*	4.82	4.81	4.72	4.70	4.73	4.82	4.69	4.79	4.67	4.29	4.71	4.54
Wo	45.0	45.0	45.0	45.3	45.3	43.8	43.7	43.7	44.2	43.9	45.2	44.8
En	47.5	47.5	47.6	47.3	47.3	48.8	49.1	48.8	48.5	49.5	47.4	48.0
Fs	7.5	7.5	7.4	7.4	7.4	7.4	7.3	7.4	7.3	6.7	7.4	7.2

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1d (cont.)

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	298	299	300	301	302	303	304	305	306	307	308	309
SiO2	54.73	54.67	54.82	54.37	54.30	54.35	54.25	54.28	54.16	54.08	51.96	14.04
TiO2	0.14	0.16	0.22	0.04	0.07	0.06	0.10	0.13	0.11	0.13	0.10	0.00
Al2O3	0.50	0.45	0.46	0.40	0.46	0.46	0.43	0.43	0.41	0.43	0.79	1.33
Cr2O3	0.10	0.10	0.04	0.10	0.06	0.11	0.09	0.07	0.06	0.05	0.11	0.00
Fe2O3	0.60	0.48	0.13	1.23	0.51	1.03	1.44	0.41	0.31	0.31	0.72	-2.49
FeO	3.32	3.78	3.88	2.89	3.57	3.08	2.71	3.48	3.64	3.70	3.71	3.74
MnO	0.11	0.16	0.10	0.12	0.13	0.15	0.12	0.12	0.13	0.12	0.14	0.00
MgO	18.39	18.03	18.37	17.06	16.50	16.83	17.47	17.39	17.29	17.08	15.65	5.21
CaO	22.11	22.07	21.93	23.13	23.45	23.42	23.17	22.88	22.66	22.98	22.30	2.71
Na2O	0.22	0.24	0.19	0.42	0.37	0.38	0.26	0.24	0.26	0.22	0.37	0.01
K20	0.01	0.02	0.01	0.02	0.04	0.02	0.03	0.01	0.02	0.02	0.07	0.08
Total	100.22	100.16	100.15	99.77	99.45	99.89	100.08	99.45	99.06	99.13	95.91	24.63
Cations Based on 6 Oxygens												
Si	1.984	1.987	1.989	1.987	1.994	1.987	1.977	1.989	1.992	1.990	1.983	2.031
Ti	0.004	0.004	0.006	0.001	0.002	0.002	0.003	0.004	0.003	0.004	0.003	0.000
Al	0.021	0.019	0.020	0.017	0.020	0.020	0.018	0.019	0.018	0.019	0.035	0.227
Cr	0.003	0.003	0.001	0.003	0.002	0.003	0.003	0.002	0.002	0.001	0.003	0.000
Fe3	0.016	0.013	0.004	0.034	0.014	0.028	0.039	0.011	0.009	0.009	0.021	-0.272
Fe2	0.101	0.115	0.118	0.088	0.110	0.094	0.083	0.107	0.112	0.114	0.118	0.453
Mn	0.003	0.005	0.003	0.004	0.004	0.005	0.004	0.004	0.004	0.004	0.005	0.000
Mg	0.994	0.977	0.994	0.930	0.904	0.917	0.949	0.949	0.948	0.937	0.890	1.124
Ca	0.859	0.859	0.852	0.906	0.923	0.917	0.905	0.898	0.893	0.906	0.912	0.420
Na	0.015	0.017	0.013	0.030	0.026	0.027	0.019	0.017	0.018	0.016	0.027	0.002
K	0.000	0.001	0.000	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.003	0.015
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.683	3.656	3.674	3.662	3.652	3.656	3.680	3.681	3.674	3.673	3.585	3.096
mg	89.4	88.4	89.1	88.4	88.0	88.2	88.6	88.9	88.7	88.4	86.5	86.1
FEO*	3.87	4.22	4.00	4.00	4.03	4.01	4.01	3.85	3.92	3.98	4.36	1.50
Wo	43.6	43.8	43.3	46.3	47.3	46.9	45.8	45.7	45.5	46.1	47.0	24.4
En	50.5	49.7	50.5	47.5	46.3	46.9	48.0	48.3	48.3	47.7	45.9	65.1
Fs	6.0	6.5	6.2	6.2	6.3	6.3	6.2	6.0	6.1	6.2	7.2	10.5

Table B.1d (cont.)

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	310	311	312	313	314	315	316	317	318	319	320	321
SiO2	54.55	54.94	54.64	54.29	54.60	54.44	54.34	53.79	54.18	54.28	54.16	53.89
TiO2	0.07	0.16	0.18	0.15	0.19	0.22	0.21	0.19	0.17	0.14	0.10	0.21
Al2O3	0.67	0.48	0.53	0.61	0.55	0.60	0.60	0.66	0.72	0.64	0.61	0.81
Cr2O3	0.06	0.03	0.08	0.05	0.04	0.15	0.18	0.14	0.06	0.03	0.00	0.00
Fe2O3	2.49	1.89	1.93	1.82	1.92	1.36	1.63	2.46	1.90	1.92	2.47	2.39
FeO	1.80	2.54	2.51	2.83	2.76	3.40	3.19	3.07	3.91	3.81	3.46	3.26
MnO	0.14	0.13	0.12	0.13	0.14	0.14	0.13	0.19	0.18	0.21	0.19	0.19
MgO	17.09	18.30	18.14	17.63	17.84	17.54	17.63	17.17	16.65	16.37	16.51	16.73
CaO	24.09	22.84	22.83	22.96	22.92	22.80	22.42	22.53	22.57	22.88	23.01	23.02
Na2O	0.43	0.25	0.26	0.26	0.29	0.26	0.35	0.36	0.48	0.52	0.49	0.39
K20	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.03	0.01	0.02
Total	101.41	101.60	101.24	100.74	101.27	100.92	100.70	100.59	100.82	100.83	100.99	100.91
Cations Based on 6 Oxygens												
Si	1.964	1.969	1.966	1.967	1.967	1.970	1.970	1.958	1.970	1.975	1.968	1.958
Ti	0.002	0.004	0.005	0.004	0.005	0.006	0.006	0.005	0.005	0.004	0.003	0.006
Al	0.029	0.020	0.022	0.026	0.023	0.026	0.026	0.028	0.031	0.028	0.026	0.035
Cr	0.002	0.001	0.002	0.001	0.001	0.004	0.005	0.004	0.002	0.001	0.000	0.000
Fe3	0.067	0.051	0.052	0.050	0.052	0.037	0.045	0.067	0.052	0.053	0.067	0.065
Fe2	0.054	0.076	0.076	0.086	0.083	0.103	0.097	0.093	0.119	0.116	0.105	0.099
Mn	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.006	0.006	0.006	0.006	0.006
Mg	0.917	0.978	0.973	0.952	0.958	0.946	0.953	0.932	0.902	0.888	0.894	0.906
Ca	0.930	0.877	0.880	0.891	0.885	0.884	0.871	0.879	0.879	0.892	0.896	0.896
Na	0.030	0.017	0.018	0.018	0.020	0.018	0.025	0.025	0.034	0.037	0.034	0.027
K	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.648	3.667	3.661	3.639	3.639	3.622	3.610	3.568	3.523	3.528	3.536	3.542
mg	88.3	88.5	88.4	87.6	87.6	87.1	87.1	85.3	84.1	84.0	83.8	84.7
FEO*	4.04	4.25	4.25	4.46	4.48	4.63	4.66	5.29	5.62	5.54	5.67	5.41
Wo	47.2	44.2	44.4	45.1	44.7	44.9	44.3	44.6	45.0	45.8	45.6	45.6
En	46.6	49.3	49.1	48.1	48.4	48.0	48.5	47.3	46.2	45.6	45.6	46.1
Fs	6.2	6.4	6.5	6.8	6.8	7.1	7.2	8.2	8.8	8.6	8.8	8.4

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1d (cont.)

OC 8-6 Clinopyroxene 1, Line Scan Traverse

	322	*323*	*324*	*325*	*326*	*327*	*328*	*329*	*330*	*331*
SiO2	54.22	53.88	53.91	53.81	53.62	53.71	55.38	20.96	1.21	6.14
TiO2	0.17	0.19	0.24	0.23	0.20	0.21	0.21	0.28	0.21	0.25
Al2O3	0.90	0.89	0.83	0.86	0.85	0.80	0.84	1.21	0.33	1.62
Cr2O3	0.00	0.00	0.01	0.00	0.03	0.03	0.00	0.06	0.08	0.06
Fe2O3	1.54	1.62	2.25	2.30	1.16	1.30	-0.88	1.05	69.94	46.80
FeO	4.12	4.03	3.52	3.57	4.42	4.08	5.96	1.78	-62.48	-40.23
MnO	0.16	0.16	0.18	0.18	0.14	0.16	0.13	0.11	0.10	0.07
MgO	16.55	16.63	17.07	16.68	16.34	16.31	16.48	4.16	0.58	1.61
CaO	22.91	22.64	22.64	22.90	22.70	22.88	22.78	10.64	48.48	33.99
Na2O	0.39	0.37	0.32	0.36	0.32	0.37	0.36	0.28	0.13	0.08
K20	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.36	0.08	0.31
Total	100.98	100.41	100.98	100.91	99.79	99.86	101.29	40.88	58.67	50.70
					Cations Based on 6 Oxygens					
Si	1.969	1.967	1.957	1.957	1.972	1.972	2.002	1.922	0.087	0.498
Ti	0.005	0.005	0.006	0.006	0.005	0.006	0.006	0.019	0.011	0.015
Al	0.039	0.038	0.036	0.037	0.037	0.034	0.036	0.131	0.028	0.155
Cr	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.004	0.005	0.004
Fe3	0.042	0.045	0.061	0.063	0.032	0.036	-0.024	0.073	3.795	2.858
Fe2	0.125	0.123	0.107	0.109	0.136	0.125	0.180	0.136	-3.767	-2.731
Mn	0.005	0.005	0.005	0.005	0.004	0.005	0.004	0.008	0.006	0.005
Mg	0.896	0.905	0.924	0.904	0.895	0.893	0.888	0.569	0.062	0.195
Ca	0.891	0.886	0.880	0.892	0.894	0.900	0.882	1.046	3.747	2.956
Na	0.028	0.026	0.023	0.025	0.023	0.026	0.025	0.049	0.019	0.013
K	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.042	0.007	0.032
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.526	3.528	3.541	3.527	3.535	3.544	3.538	3.144	5.570	4.381
mg	84.3	84.4	84.6	84.1	84.2	84.7	85.1	73.1	69.2	60.4
FEO*	5.51	5.49	5.54	5.64	5.46	5.25	5.16	2.73	0.46	1.88
Wo	45.6	45.2	44.6	45.3	45.7	46.1	45.8	57.3	97.7	90.2
En	45.8	46.2	46.8	45.9	45.7	45.7	46.1	31.2	1.6	5.9
Fs	8.6	8.6	8.5	8.7	8.6	8.3	8.1	11.5	0.7	3.9

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1e

OC8-9 Clinopyroxene Compositions

	CORE 8,1	*CORE 8,2*	*CORE 7,1*	*RIM 7,2*	*CORE 5,1*	*RIM 5,2*	*CORE 10,1*	*RIM 10,2*	*CORE 2,1*	*RIM 2,2*	*CORE 1,1*	*RIM 1,2*
SiO2	54.47	54.99	54.60	54.75	54.91	54.79	53.95	53.58	54.95	55.51	55.09	55.22
TiO2	0.10	0.22	0.18	0.25	0.20	0.19	0.20	0.22	0.08	0.21	0.19	0.19
Al2O3	1.04	0.55	0.58	0.54	0.52	0.58	0.65	0.61	0.92	0.61	0.58	0.39
Cr2O3	0.00	0.00	0.01	0.02	0.00	0.05	0.05	0.00	0.00	0.02	0.00	0.02
Fe2O3	1.28	0.72	0.48	0.43	0.22	0.57	1.23	1.74	0.42	0.00	0.00	0.00
FeO	3.93	3.80	3.88	3.84	4.02	3.65	3.43	2.83	4.79	4.14	4.31	3.71
MnO	0.11	0.15	0.10	0.07	0.01	0.10	0.08	0.07	0.20	0.11	0.10	0.07
MgO	16.05	17.17	17.02	17.46	17.44	17.22	17.38	17.11	16.60	17.32	17.20	17.72
CaO	22.89	23.61	23.57	23.06	23.29	23.46	22.75	23.16	22.44	23.17	22.97	23.44
Na2O	0.70	0.25	0.20	0.24	0.19	0.25	0.23	0.26	0.53	0.20	0.23	0.18
K20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.57	101.46	100.62	100.66	100.80	100.87	99.95	99.58	100.93	101.29	100.67	100.94
Cations Based on 6 Oxygens												
Si	1.982	1.981	1.983	1.984	1.987	1.983	1.971	1.966	1.991	1.997	1.995	1.992
Ti	0.003	0.006	0.005	0.007	0.005	0.005	0.005	0.006	0.002	0.006	0.005	0.005
Al	0.044	0.023	0.025	0.023	0.022	0.025	0.028	0.026	0.039	0.026	0.025	0.017
Cr	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Fe3	0.035	0.019	0.013	0.012	0.006	0.016	0.034	0.048	0.011	0.000	0.000	0.000
Fe2	0.120	0.115	0.118	0.117	0.122	0.110	0.105	0.087	0.145	0.125	0.131	0.112
Mn	0.003	0.005	0.003	0.002	0.000	0.003	0.002	0.002	0.006	0.003	0.003	0.002
Mg	0.871	0.922	0.921	0.943	0.941	0.929	0.946	0.936	0.896	0.929	0.928	0.953
Ca	0.892	0.911	0.917	0.895	0.903	0.910	0.890	0.911	0.871	0.893	0.891	0.906
Na	0.050	0.017	0.014	0.017	0.013	0.018	0.016	0.018	0.037	0.014	0.016	0.012
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	3.992	3.995	4.000
DS	3.501	3.635	3.647	3.650	3.664	3.651	3.628	3.639	3.520	3.646	3.635	3.704
mg	84.9	87.3	87.6	88.0	88.0	88.1	87.2	87.4	85.1	88.2	87.7	89.5
FEO*	5.08	4.45	4.31	4.23	4.22	4.17	4.54	4.40	5.17	4.14	4.31	3.71
Wo	46.5	46.3	46.6	45.5	45.8	46.3	45.1	46.0	45.3	45.9	45.7	46.0
En	45.4	46.9	46.8	48.0	47.7	47.3	47.9	47.2	46.6	47.7	47.6	48.3
Fs	8.1	6.8	6.7	6.5	6.5	6.4	7.0	6.8	8.1	6.4	6.7	5.7

Table B.1e (cont.)

OC8-9 Clinopyroxene Compositions

	CORE 9,1	*RIM 9,2*	*CORE 4,1*	*RIM 4,2*	*CORE 3,1*	*RIM 3,2*	*CORE 6,1*	*RIM 6,2*
SiO2	54.89	54.53	54.89	54.96	55.04	55.50	54.97	54.66
TiO2	0.11	0.17	0.12	0.22	0.11	0.18	0.09	0.23
Al2O3	0.99	0.79	0.98	0.57	0.94	0.73	1.11	0.70
Cr2O3	0.00	0.00	0.02	0.01	0.02	0.00	0.00	0.00
Fe2O3	0.54	0.91	1.06	1.00	0.20	-0.51	1.31	0.02
FeO	4.74	4.18	4.19	3.26	5.08	4.87	4.05	4.25
MnO	0.16	0.16	0.11	0.09	0.13	0.16	0.07	0.03
MgO	16.41	16.57	16.44	17.42	16.50	16.74	15.76	17.10
CaO	22.51	23.07	22.83	23.61	22.93	23.40	22.74	23.20
Na2O	0.59	0.42	0.62	0.27	0.41	0.37	0.96	0.24
K20	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Total	100.93	100.80	101.27	101.41	101.36	101.44	101.06	100.43
Cations Based on 6 Oxygens								
Si	1.989	1.981	1.983	1.978	1.988	1.999	1.990	1.987
Ti	0.003	0.004	0.003	0.006	0.003	0.005	0.002	0.006
Al	0.042	0.034	0.042	0.024	0.040	0.031	0.047	0.030
Cr	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000
Fe3	0.015	0.025	0.029	0.027	0.005	-0.014	0.036	0.001
Fe2	0.144	0.127	0.126	0.098	0.154	0.147	0.123	0.129
Mn	0.005	0.005	0.003	0.003	0.004	0.005	0.002	0.001
Mg	0.887	0.897	0.885	0.934	0.888	0.899	0.850	0.926
Ca	0.874	0.898	0.884	0.910	0.887	0.903	0.882	0.903
Na	0.042	0.029	0.043	0.019	0.029	0.026	0.068	0.017
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.505	3.559	3.514	3.654	3.531	3.598	3.455	3.632
mg	84.9	85.5	85.1	88.2	84.8	87.1	84.3	87.7
FEO*	5.22	5.00	5.14	4.16	5.26	4.41	5.23	4.27
Wo	45.5	46.1	45.9	46.2	45.9	46.7	46.7	46.1
En	46.2	46.1	46.0	47.4	45.9	46.5	45.0	47.3
Fs	8.2	7.8	8.1	6.4	8.2	6.9	8.4	6.6

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1f

OC 8-12 Clinopyroxene Compositions

	CORE 1,1	*RIM 1,2*	*MID 1,3*	*CORE 2,1*	*RIM 2,2*	*RIM 2,3*	*CORE 3,1*	*RIM 3,2*	*RIM 3,3*	*RIM 3,4*	*CORE 4,1*	*RIM 4,2*
SiO2	54.41	54.12	54.39	54.24	54.11	54.33	54.20	54.46	54.56	54.13	53.89	54.62
TiO2	0.22	0.14	0.19	0.20	0.19	0.20	0.18	0.20	0.21	0.20	0.20	0.16
Al2O3	0.98	1.13	0.96	0.95	1.02	1.08	1.07	1.11	1.00	1.03	0.97	0.83
Cr2O3	0.09	0.07	0.10	0.06	0.11	0.19	0.16	0.17	0.13	0.13	0.08	0.15
Fe2O3	1.13	1.55	1.09	1.45	1.05	1.42	1.01	1.20	0.57	1.37	2.66	0.44
FeO	3.65	3.73	3.60	3.09	3.64	3.29	3.64	3.97	3.92	3.51	1.95	3.28
MnO	0.17	0.19	0.12	0.16	0.10	0.13	0.13	0.13	0.13	0.09	0.13	0.10
MgO	16.52	16.14	16.79	16.97	16.64	16.90	16.82	16.48	16.69	16.67	17.33	17.51
CaO	23.66	23.25	23.49	23.33	23.28	23.21	23.25	23.40	23.36	23.27	23.40	23.07
Na2O	0.36	0.51	0.31	0.36	0.36	0.39	0.30	0.40	0.37	0.38	0.36	0.28
K20	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.01	0.00	0.00
Total	101.19	100.83	101.04	100.80	100.50	101.16	100.77	101.52	100.94	100.79	100.98	100.44
Cations Based on 6 Oxygens												
Si	1.969	1.968	1.969	1.966	1.969	1.963	1.967	1.966	1.976	1.965	1.949	1.980
Ti	0.006	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.005	0.005	0.004
Al	0.042	0.048	0.041	0.040	0.044	0.046	0.046	0.047	0.043	0.044	0.042	0.036
Cr	0.003	0.002	0.003	0.002	0.003	0.005	0.005	0.005	0.004	0.004	0.002	0.004
Fe3	0.031	0.042	0.030	0.039	0.029	0.039	0.028	0.033	0.016	0.037	0.072	0.012
Fe2	0.111	0.113	0.109	0.094	0.111	0.100	0.111	0.120	0.119	0.106	0.059	0.100
Mn	0.005	0.006	0.004	0.005	0.003	0.004	0.004	0.004	0.004	0.003	0.004	0.003
Mg	0.891	0.875	0.906	0.917	0.903	0.911	0.910	0.887	0.901	0.902	0.934	0.946
Ca	0.917	0.906	0.911	0.906	0.908	0.899	0.904	0.905	0.907	0.905	0.907	0.896
Na	0.025	0.036	0.022	0.025	0.025	0.027	0.021	0.028	0.026	0.027	0.026	0.020
K	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.570	3.513	3.588	3.594	3.575	3.569	3.580	3.536	3.580	3.565	3.606	3.655
mg	86.3	84.9	86.7	87.3	86.6	86.8	86.8	85.3	87.0	86.3	87.7	89.4
FEO*	4.67	5.12	4.58	4.39	4.58	4.57	4.55	5.05	4.43	4.74	4.35	3.68
Wo		46.8	46.6	46.3	46.6	46.1	46.3	46.5	46.7	46.4	46.0	45.9
En	45.7	45.2	46.3	46.9	46.3	46.8	46.6	45.6	46.4	46.2	47.4	48.4
Fs	7.3	8.0	7.1	6.8	7.2	7.1	7.1	7.8	6.9	7.4	6.7	5.7

Table B.1f (cont.)

OC 8-12 Clinopyroxene Compositions

	CORE 5,1	*RIM 5,2*	*RIM 5,3*	*CORE 6,1*	*RIM 6,2*	*CORE 7,1*	*RIM 7,2*	*RIM 7,3*	*CORE 8,1*	*RIM 8,2*	*CORE 9,1*	*RIM 9,2*
SiO2	54.34	53.66	54.67	54.39	54.43	54.55	54.02	54.16	54.52	54.47	54.17	53.89
TiO2	0.21	0.22	0.17	0.21	0.16	0.21	0.22	0.20	0.21	0.19	0.21	0.20
Al2O3	0.98	1.22	0.97	1.08	0.87	1.05	1.03	0.94	0.93	1.18	0.96	1.12
Cr2O3	0.20	0.09	0.15	0.07	0.08	0.16	0.11	0.13	0.12	0.10	0.08	0.09
Fe2O3	0.76	1.77	0.31	0.91	0.48	0.25	1.25	0.86	0.34	0.09	1.47	1.49
FeO	3.82	3.43	4.20	3.84	3.89	3.65	3.27	3.75	4.14	5.09	3.21	4.04
MnO	0.09	0.20	0.18	0.15	0.13	0.10	0.19	0.18	0.16	0.23	0.06	0.16
MgO	16.72	16.12	16.61	16.55	16.81	17.32	16.95	16.67	16.83	16.06	16.91	16.21
CaO	23.37	23.34	23.30	23.26	23.26	23.04	23.02	23.28	23.05	22.85	23.28	23.17
Na2O	0.32	0.45	0.37	0.42	0.31	0.28	0.36	0.32	0.33	0.45	0.37	0.39
K20	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	100.82	100.51	100.94	100.88	100.42	100.62	100.41	100.50	100.63	100.71	100.72	100.78
Cations Based on 6 Oxygens												
Si	1.972	1.958	1.981	1.973	1.980	1.976	1.966	1.972	1.980	1.983	1.966	1.963
Ti	0.006	0.006	0.005	0.006	0.004	0.006	0.006	0.005	0.006	0.005	0.006	0.006
Al	0.042	0.053	0.041	0.046	0.037	0.045	0.044	0.040	0.040	0.050	0.041	0.048
Cr	0.006	0.003	0.004	0.002	0.002	0.004	0.003	0.004	0.004	0.003	0.002	0.002
Fe3	0.021	0.049	0.008	0.025	0.013	0.007	0.034	0.024	0.009	0.002	0.040	0.041
Fe2	0.116	0.105	0.127	0.116	0.118	0.111	0.100	0.114	0.126	0.155	0.097	0.123
Mn	0.003	0.006	0.005	0.005	0.004	0.003	0.006	0.006	0.005	0.007	0.002	0.005
Mg	0.904	0.877	0.897	0.894	0.912	0.935	0.919	0.905	0.911	0.871	0.914	0.880
Ca	0.908	0.912	0.905	0.904	0.907	0.894	0.897	0.908	0.897	0.891	0.905	0.904
Na	0.023	0.032	0.026	0.029	0.022	0.019	0.025	0.022	0.023	0.032	0.026	0.028
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.586	3.514	3.576	3.553	3.606	3.621	3.581	3.584	3.585	3.497	3.587	3.512
mg	86.9	85.1	86.9	86.4	87.4	88.8	87.3	86.8	87.1	84.7	86.9	84.3
FEO*	4.50	5.03	4.48	4.66	4.32	3.88	4.39	4.53	4.45	5.17	4.53	5.39
Wo	46.6	47.0	46.7	46.6	46.5	45.9	46.0	46.6	46.2	46.4	46.3	46.4
En	46.4	45.1	46.3	46.1	46.8	48.0	47.1	46.4	46.9	45.4	46.7	45.2
Fs	7.0	7.9	7.0	7.3	6.7	6.0	6.9	7.1	7.0	8.2	7.0	8.4

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1f (cont.)

OC 8-12 Clinopyroxene Compositions

	CORE 10,1	***RIM 10,2***	***CORE 11,1***	***CORE 11,2***	***RIM 11,3***	***CORE 11,4***	***CORE 12,1***	***CORE 12,2***	***RIM 12,3***	***CORE 12,4***	***CORE 13,1***	***RIM 13,2***
SiO2	54.58	54.65	54.45	53.40	53.36	53.25	52.77	53.33	52.19	52.73	52.75	53.01
TiO2	0.19	0.18	0.15	0.14	0.17	0.21	0.16	0.18	0.21	0.16	0.16	0.18
Al2O3	0.71	0.92	0.75	1.00	0.97	1.04	0.95	0.83	1.20	0.87	0.95	0.98
Cr2O3	0.26	0.19	0.10	0.12	0.14	0.11	0.02	0.28	0.12	0.20	0.15	0.06
Fe2O3		1.07	1.30	2.82	2.89	2.91	3.68	2.12	4.53	4.38	3.55	3.75
FeO	3.24	2.83	2.26	1.99	2.12	2.41	1.41	1.81	1.07	-0.04	1.31	1.23
MnO	0.09	0.09	0.10	0.16	0.15	0.15	0.20	0.14	0.16	0.14	0.15	0.11
MgO	17.53	17.65	17.83	17.57	17.26	16.92	17.39	18.02	16.73	18.23	17.42	17.14
CaO	23.09	23.20	23.28	22.78	22.94	23.01	22.73	22.42	23.01	22.84	22.95	23.24
Na2O	0.23	0.30	0.28	0.28	0.33	0.36	0.33	0.24	0.44	0.29	0.28	0.41
K20	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Total	99.94	101.09	100.50	100.27	100.33	100.37	99.64	99.37	99.66	99.80	99.67	100.11
Cations Based on 6 Oxygens												
Si	1.986	1.969	1.970	1.945	1.945	1.943	1.935	1.953	1.920	1.924	1.934	1.936
Ti	0.005	0.005	0.004	0.004	0.005	0.006	0.004	0.005	0.006	0.004	0.004	0.005
Al	0.030	0.039	0.032	0.043	0.042	0.045	0.041	0.036	0.052	0.037	0.041	0.042
Cr	0.007	0.005	0.003	0.003	0.004	0.003	0.001	0.008	0.003	0.006	0.004	0.002
Fe3		0.029	0.036	0.077	0.079	0.080	0.101	0.059	0.125	0.120	0.098	0.103
Fe2	0.099	0.085	0.068	0.061	0.065	0.074	0.043	0.056	0.033	-0.001	0.040	0.037
Mn	0.003	0.003	0.003	0.005	0.005	0.005	0.006	0.004	0.005	0.004	0.005	0.003
Mg	0.951	0.948	0.962	0.953	0.937	0.920	0.951	0.983	0.917	0.991	0.952	0.933
Ca	0.900	0.896	0.903	0.889	0.896	0.899	0.893	0.879	0.907	0.893	0.902	0.910
Na	0.016	0.021	0.019	0.020	0.024	0.025	0.023	0.017	0.031	0.021	0.020	0.029
K	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3.998	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.692	3.646	3.686	3.603	3.587	3.556	3.591	3.665	3.532	3.666	3.613	3.592
mg	90.6	89.3	90.2	87.4	86.7	85.7	86.8	89.6	85.3	89.3	87.3	86.9
FEO*	3.24	3.79	3.43	4.53	4.72	5.03	4.72	3.72	5.14	3.90	4.50	4.60
Wo	46.2	45.7	45.9	44.9	45.3	45.6	44.9	44.5	45.8	44.6	45.3	45.9
En	48.8	48.4	48.9	48.2	47.4	46.6	47.8	49.7	46.3	49.5	47.8	47.1
Fs	5.1	5.8	5.3	7.0	7.3	7.8	7.3	5.8	8.0	5.9	6.9	7.1

Table B.1f (cont.)

OC 8-12 Clinopyroxene Compositions

	CORE 14,1	***CORE 14,2***	***RIM 14,3***	***RIM 14,4***	***CORE 15,1***	***CORE 15,2***	***RIM 15,3***	***RIM 15,4***	***CORE 16,1***	***RIM 16,2***	***CORE 17,1***	***CORE 17,2***
SiO2	53.46	53.62	52.92	53.13	52.16	53.84	52.63	52.93	52.45	52.48	53.39	52.62
TiO2	0.15	0.21	0.08	0.13	0.19	0.16	0.19	0.21	0.18	0.20	0.15	0.16
Al2O3	0.74	0.80	1.06	1.13	1.07	0.73	0.91	1.24	1.13	1.13	1.03	0.92
Cr2O3	0.32	0.10	0.09	0.19	0.08	0.17	0.12	0.10	0.10	0.13	0.10	0.14
Fe2O3	2.60	2.45	4.15	3.27	4.81	1.91	3.97	2.31	4.96	4.32	3.14	3.89
FeO	0.80	1.96	1.19	2.41	0.56	1.99	0.63	3.18	0.72	1.35	1.97	0.27
MnO	0.10	0.12	0.16	0.18	0.15	0.12	0.16	0.20	0.13	0.17	0.16	0.11
MgO	18.19	17.88	16.57	16.38	17.43	17.95	17.73	16.19	17.03	16.99	17.07	17.93
CaO	23.19	22.92	23.25	22.92	22.96	22.93	23.02	22.75	23.17	22.82	22.98	22.82
Na2O	0.22	0.21	0.58	0.54	0.29	0.22	0.26	0.46	0.43	0.41	0.42	0.32
K20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Total	99.77	100.28	100.06	100.28	99.70	100.02	99.62	99.56	100.31	100.00	100.42	99.18
Cations Based on 6 Oxygens												
Si	1.948	1.950	1.937	1.944	1.914	1.959	1.928	1.950	1.916	1.923	1.944	1.931
Ti	0.004	0.006	0.002	0.004	0.005	0.004	0.005	0.006	0.005	0.005	0.004	0.004
Al	0.032	0.034	0.046	0.049	0.046	0.031	0.039	0.054	0.049	0.049	0.044	0.040
Cr	0.009	0.003	0.003	0.005	0.002	0.005	0.003	0.003	0.003	0.004	0.003	0.004
Fe3	0.071	0.067	0.114	0.090	0.133	0.052	0.109	0.064	0.136	0.119	0.086	0.108
Fe2	0.024	0.060	0.036	0.074	0.017	0.061	0.019	0.098	0.022	0.041	0.060	0.008
Mn	0.003	0.004	0.005	0.005	0.005	0.004	0.005	0.006	0.004	0.005	0.005	0.003
Mg	0.988	0.969	0.904	0.893	0.954	0.974	0.968	0.889	0.927	0.928	0.927	0.981
Ca	0.905	0.893	0.912	0.898	0.903	0.894	0.903	0.898	0.907	0.896	0.897	0.897
Na	0.016	0.015	0.041	0.038	0.021	0.016	0.019	0.033	0.031	0.029	0.029	0.023
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.722	3.649	3.545	3.506	3.586	3.679	3.639	3.498	3.547	3.537	3.567	3.660
mg	91.2	88.4	85.7	84.5	86.4	89.6	88.3	84.6	85.4	85.3	86.4	89.4
FEO*	3.14	4.17	4.93	5.35	4.89	3.71	4.20	5.25	5.19	5.24	4.80	3.77
Wo	45.5	44.9	46.4	45.9	45.0	45.1	45.2	46.1	45.5	45.2	45.5	45.0
En	49.7	48.7	46.0	45.7	47.5	49.2	48.4	45.6	46.5	46.8	47.1	49.2
Fs	4.8	6.4	7.7	8.4	7.5	5.7	6.4	8.3	8.0	8.1	7.4	5.8

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1g

OC 8-17 Clinopyroxene Compositions

	CORE 8,1	*CORE 3,1*	*RIM 3,2*	*RIM 1,1*	*RIM 1,2*	*CORE 7,1*	*CORE 4,1*	*CORE 5,1*	*CORE 5,2*	*CORE 1,1*	*RIM 1,2*	*CORE 2,1*
SiO2	54.25	54.62	54.57	54.79	54.11	52.40	54.35	53.94	54.30	53.35	53.71	54.31
TiO2	0.22	0.18	0.19	0.21	0.11	0.34	0.18	0.23	0.11	0.27	0.09	0.18
Al2O3	0.86	0.80	0.82	0.82	1.63	2.03	0.76	0.94	1.83	1.31	1.71	0.90
Cr2O3	0.00	0.00	0.03	0.06	0.03	0.03	0.01	0.02	0.02	0.06	0.00	0.00
Fe2O3	0.04	-0.98	-1.04	-0.76	0.91	1.48	-1.16	-0.58	-0.45	0.79	2.38	0.78
FeO	5.81	5.92	6.30	5.22	6.09	6.12	6.09	5.82	7.39	5.74	4.49	4.30
MnO	0.15	0.10	0.15	0.14	0.18	0.20	0.10	0.14	0.20	0.15	0.20	0.17
MgO	16.10	16.39	16.09	17.18	13.94	14.55	16.63	16.05	13.85	15.39	14.47	16.69
CaO	22.52	22.68	22.63	22.23	21.81	21.88	21.97	22.56	21.53	22.59	22.09	23.00
Na2O	0.34	0.26	0.28	0.26	1.23	0.58	0.25	0.26	1.11	0.38	1.20	0.31
K20	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Total	100.29	99.97	100.03	100.17	100.05	99.61	99.19	99.37	99.88	100.03	100.34	100.64
					Cations Based on 6 Oxygens							
Si	1.987	2.000	2.001	1.996	1.993	1.945	2.004	1.990	2.003	1.966	1.970	1.976
Ti	0.006	0.005	0.005	0.006	0.003	0.010	0.005	0.006	0.003	0.007	0.003	0.005
Al	0.037	0.035	0.035	0.035	0.071	0.089	0.033	0.041	0.080	0.057	0.074	0.039
Cr	0.000	0.000	0.001	0.002	0.001	0.001	0.000	0.001	0.001	0.002	0.000	0.000
Fe3	0.001	-0.027	-0.029	-0.021	0.025	0.041	-0.032	-0.016	-0.013	0.022	0.066	0.021
Fe2	0.178	0.181	0.193	0.159	0.188	0.190	0.188	0.179	0.228	0.177	0.138	0.131
Mn	0.005	0.003	0.005	0.004	0.006	0.006	0.003	0.005	0.006	0.005	0.006	0.005
Mg	0.879	0.895	0.880	0.933	0.765	0.805	0.914	0.883	0.761	0.845	0.791	0.905
Ca	0.884	0.890	0.889	0.867	0.860	0.870	0.868	0.892	0.851	0.892	0.868	0.897
Na	0.024	0.019	0.020	0.018	0.088	0.042	0.018	0.019	0.080	0.027	0.085	0.022
K	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.499	3.561	3.533	3.589	3.246	3.256	3.561	3.528	3.229	3.417	3.276	3.561
mg	83.1	85.3	84.2	87.1	78.3	77.7	85.4	84.4	78.0	81.0	79.6	85.6
FEO*	5.85	5.04	5.37	4.54	6.91	7.45	5.05	5.29	6.98	6.45	6.63	5.00
Wo	45.5	45.9	46.0	44.7	46.8	45.6	44.8	46.0	46.6	46.1	46.6	45.9
En	45.3	46.1	45.5	48.1	41.6	42.2	47.2	45.6	41.7	43.7	42.5	46.3
Fs	9.2	8.0	8.5	7.1	11.6	12.1	8.0	8.4	11.8	10.3	10.9	7.8

Table B.1g (cont.)

OC 8-17 Clinopyroxene Compositions

	RIM 2,2	*CORE 3,1*	*RIM 3,2*	*CORE 4,1*	*CORE 4,2*	*CORE 4,3*	*CORE 4,4*	*CORE 5,1*	*RIM 5,2*	*CORE 6,1*	*RIM 6,2*	*RIM 6,3*
SiO2	53.72	53.87	54.89	53.97	54.04	52.10	54.62	53.40	54.34	54.11	54.44	54.48
TiO2	0.18	0.22	0.21	0.20	0.20	0.27	0.06	0.24	0.21	0.22	0.13	0.11
Al2O3	1.75	0.97	0.86	0.82	0.75	2.03	1.69	1.44	0.98	1.51	1.98	1.99
Cr2O3	0.00	0.02	0.01	0.00	0.04	0.00	0.00	0.09	0.04	0.02	0.03	0.01
Fe2O3	2.17	1.86	1.40	1.35	3.22	2.62	2.70	1.93	2.25	1.19	2.61	2.35
FeO	5.04	4.48	3.17	4.03	1.67	4.87	4.24	4.69	3.51	4.92	4.57	4.89
MnO	0.22	0.26	0.07	0.13	0.11	0.22	0.24	0.18	0.17	0.11	0.14	0.21
MgO	14.77	15.93	17.84	16.87	16.94	14.09	14.32	15.74	16.88	15.86	14.04	13.95
CaO	22.52	22.86	23.04	22.86	23.73	22.75	22.01	22.56	23.27	23.07	21.82	21.82
Na2O	0.85	0.46	0.25	0.25	0.31	0.69	1.54	0.48	0.34	0.45	1.62	1.58
K20	0.00	0.02	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Total	101.22	100.95	101.77	100.50	101.01	99.65	101.42	100.75	101.99	101.46	101.38	101.39
					Cations Based on 6 Oxygens							
Si	1.958	1.964	1.967	1.967	1.955	1.936	1.980	1.952	1.955	1.961	1.975	1.978
Ti	0.005	0.006	0.006	0.006	0.006	0.008	0.002	0.006	0.006	0.006	0.003	0.003
Al	0.075	0.042	0.036	0.035	0.032	0.089	0.072	0.062	0.041	0.064	0.085	0.085
Cr	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.003	0.001	0.001	0.001	0.000
Fe3	0.059	0.051	0.038	0.037	0.088	0.073	0.074	0.053	0.061	0.032	0.071	0.064
Fe2	0.154	0.137	0.095	0.123	0.051	0.151	0.129	0.143	0.105	0.149	0.139	0.149
Mn	0.007	0.008	0.002	0.004	0.003	0.007	0.007	0.006	0.005	0.003	0.004	0.007
Mg	0.802	0.866	0.953	0.916	0.913	0.780	0.774	0.857	0.905	0.856	0.759	0.755
Ca	0.880	0.893	0.885	0.893	0.920	0.906	0.855	0.884	0.897	0.896	0.849	
Na	0.060	0.032	0.017	0.018	0.022	0.049	0.108	0.034	0.024	0.031	0.114	0.111
K	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.296	3.463	3.622	3.564	3.625	3.265	3.237	3.406	3.533	3.437	3.186	3.180
mg	79.0	82.2	87.8	85.1	86.9	77.6	79.3	81.3	84.5	82.5	78.3	78.0
FEO*	6.99	6.15	4.43	5.25	4.57	7.23	6.67	6.43	5.53	5.99	6.92	7.00
Wo	46.4	45.9	44.9	45.3	46.7	47.4	46.7	45.6	45.6	46.3	46.7	46.7
En	42.3	44.5	48.4	46.5	46.3	40.8	42.3	44.2	46.0	44.3	41.8	
Fs	11.2	9.6	6.7	8.1	7.0	11.8	11.0	10.1	8.5	9.4	11.6	11.7

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1g (cont.)

OC 8-17 Clinopyroxene Compositions

	RIM 6,4	***CORE 7,1***	***RIM 7,2***	***CORE 8,1***	***RIM 8,2***	***CORE 9,1***	***RIM 9,2***	***CORE 10,1***	***RIM(1) 10,2***	***RIM(2) 10,3***	***CORE 10,4***	***CORE 11,1***
SiO2	55.24	54.26	54.18	54.10	55.25	52.63	52.94	51.97	53.38	53.16	52.66	53.02
TiO2	0.24	0.21	0.18	0.24	0.21	0.21	0.27	0.23	0.08	0.22	0.15	0.23
Al2O3	0.81	0.86	0.92	0.89	0.86	0.97	1.78	0.93	1.93	0.86	0.95	1.34
Cr2O3	0.01	0.04	0.04	0.04	0.05	0.03	0.03	0.02	0.04	0.01	0.08	0.07
Fe2O3	0.50	1.92	1.61	1.53	1.37	1.70	2.15	4.74	3.93	3.52	3.53	2.78
FeO	4.05	3.47	4.22	3.86	3.28	4.06	5.08	0.89	3.29	1.11	2.05	3.92
MnO	0.11	0.14	0.18	0.22	0.11	0.12	0.21	0.12	0.21	0.12	0.11	0.19
MgO	17.92	16.87	16.38	16.58	17.93	15.84	14.76	17.36	14.31	18.49	17.28	16.03
CaO	22.85	23.56	23.38	23.39	23.00	22.77	22.59	22.65	21.45	22.32	22.63	22.50
Na2O	0.18	0.25	0.30	0.28	0.30	0.33	0.64	0.30	1.60	0.21	0.24	0.45
K20	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Total	101.92	101.58	101.39	101.13	102.38	98.66	100.46	99.21	100.22	100.02	99.68	100.53
					Cations Based on 6 Oxygens							
Si	1.976	1.959	1.963	1.963	1.968	1.960	1.947	1.918	1.958	1.935	1.934	1.942
Ti	0.006	0.006	0.005	0.006	0.006	0.006	0.007	0.006	0.002	0.006	0.004	0.006
Al	0.034	0.036	0.039	0.038	0.036	0.043	0.077	0.040	0.084	0.037	0.041	0.058
Cr	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.002	0.002
Fe3	0.013	0.052	0.044	0.042	0.037	0.048	0.059	0.132	0.109	0.096	0.098	0.077
Fe2	0.121	0.105	0.128	0.117	0.098	0.126	0.156	0.028	0.101	0.034	0.063	0.120
Mn	0.003	0.004	0.006	0.007	0.003	0.004	0.006	0.004	0.007	0.004	0.003	0.006
Mg	0.956	0.908	0.885	0.897	0.952	0.879	0.809	0.955	0.783	1.003	0.946	0.875
Ca	0.876	0.911	0.908	0.909	0.878	0.909	0.890	0.896	0.843	0.871	0.891	0.883
Na	0.013	0.018	0.021	0.020	0.021	0.024	0.046	0.021	0.114	0.015	0.017	0.032
K	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.621	3.573	3.527	3.552	3.610	3.513	3.311	3.577	3.198	3.646	3.576	3.425
mg	87.6	85.3	83.7	84.9	87.6	83.5	79.0	85.7	78.9	88.5	85.5	81.7
FEO*	4.50	5.20	5.67	5.24	4.51	5.59	7.01	5.16	6.83	4.28	5.23	6.42
Wo	44.5	46.1	46.2	46.3	44.7	46.3	46.5	44.6	45.9	43.4	44.6	45.2
En	48.6	45.9	45.0	45.6	48.5	44.8	42.3	47.5	42.6	50.1	47.4	44.8
Fs	6.9	7.9	8.7	8.1	6.8	8.9	11.3	7.9	11.4	6.5	8.0	10.1

Table B.1g (cont.)

OC 8-17 Clinopyroxene Compositions

	RIM 11,2
SiO2	51.86
TiO2	0.27
Al2O3	1.87
Cr2O3	0.03
Fe2O3	4.512
FeO	3.24
MnO	0.17
MgO	15.59
CaO	22.3
Na2O	0.54
K20	0
Total	100.4
	Cations Based on 6 Oxygens
Si	1.908
Ti	0.007
Al	0.081
Cr	8E-04
Fe3	0.125
Fe2	0.1
Mn	0.005
Mg	0.855
Ca	0.879
Na	0.038
K	0
Total	4
DS	3.321
mg	79.18
FEO*	7.3
Wo	44.88
En	43.64
Fs	11.47

FEO*: Total Fe

mg=Mg/(Mg+total Fe)*100

DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1h

AU 26-5 Clinopyroxene Compositions

	CORE 4,1	*CORE 4,2*	*RIM 4,3*	*CORE 7,1*	*CORE 7,2*	*RIM 7,3*	*RIM 7,4*	*RIM 7,5*	*CORE 1,1*	*CORE 1,2*	*CORE 5,1*	*RIM 5,2*
SiO2	52.49	52.42	53.14	53.67	53.46	53.00	53.28	53.65	52.87	53.43	53.50	52.42
TiO2	0.32	0.23	0.20	0.19	0.16	0.21	0.24	0.22	0.17	0.27	0.23	0.26
Al2O3	1.23	0.75	0.70	0.61	0.56	0.68	0.72	0.76	0.75	0.78	0.64	1.58
Cr2O3	0.00	0.00	0.10	0.05	0.02	0.01	0.03	0.11	0.09	0.07	0.02	0.02
Fe2O3	1.53	2.26	1.64	1.50	1.74	2.30	2.90	2.13	2.75	1.82	1.60	2.50
FeO	4.02	3.55	2.68	2.42	2.34	2.32	1.98	2.64	2.59	3.02	2.55	2.63
MnO	0.12	0.20	0.11	0.19	0.10	0.11	0.17	0.08	0.08	0.11	0.05	0.10
MgO	16.00	16.69	16.93	17.22	17.35	17.02	17.14	17.19	16.59	16.99	17.59	16.18
CaO	22.37	21.99	23.01	23.28	23.30	23.04	23.36	23.22	23.04	22.74	22.92	23.14
Na2O	0.37	0.26	0.27	0.26	0.19	0.28	0.28	0.27	0.35	0.34	0.18	0.36
K20	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Total	98.45	98.36	98.78	99.39	99.21	98.97	100.11	100.27	99.28	99.56	99.28	99.20
Cations Based on 6 Oxygens												
Si	1.956	1.955	1.965	1.969	1.966	1.957	1.947	1.956	1.952	1.962	1.964	1.936
Ti	0.009	0.006	0.006	0.005	0.005	0.006	0.006	0.006	0.005	0.007	0.006	0.007
Al	0.054	0.033	0.031	0.026	0.024	0.030	0.031	0.033	0.033	0.034	0.028	0.069
Cr	0.000	0.000	0.003	0.001	0.001	0.000	0.001	0.003	0.003	0.002	0.001	0.001
Fe3	0.043	0.064	0.046	0.042	0.048	0.064	0.080	0.059	0.076	0.050	0.044	0.069
Fe2	0.125	0.111	0.083	0.074	0.072	0.072	0.061	0.081	0.080	0.093	0.078	0.081
Mn	0.004	0.006	0.003	0.006	0.003	0.003	0.005	0.002	0.002	0.004	0.002	0.003
Mg	0.889	0.928	0.933	0.942	0.951	0.937	0.934	0.934	0.913	0.930	0.963	0.891
Ca	0.893	0.879	0.911	0.915	0.918	0.911	0.915	0.907	0.911	0.895	0.902	0.916
Na	0.027	0.019	0.020	0.019	0.013	0.020	0.020	0.019	0.025	0.024	0.013	0.026
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.488	3.542	3.638	3.669	3.685	3.630	3.618	3.620	3.581	3.592	3.671	3.508
mg	84.1	84.2	87.9	89.1	88.8	87.4	86.9	87.0	85.4	86.7	88.7	85.5
FEO*	5.40	5.59	4.16	3.77	3.90	4.39	4.59	4.56	5.06	4.65	3.99	4.88
Wo	45.8	44.4	46.2	46.4	46.2	45.9	46.0	45.8	46.0	45.5	45.4	46.8
En	45.6	46.8	47.3	47.7	47.8	47.2	46.9	47.2	46.1	47.3	48.5	45.5
Fs	8.6	8.8	6.5	5.9	6.0	6.8	7.1	7.0	7.9	7.3	6.2	7.7

Table B.1h (cont.)

AU 26-5 Clinopyroxene Compositions

	CORE 5,3	*CORE 5,4*	*CORE 6,1*	*RIM 6,2*	*RIM 6,3*	*CORE 2,1*	*CORE 2,2*	*CORE 2, 3*	*CORE 2,4*	*CORE 3,1*	*CORE 3,2*	*CORE 3,3*
SiO2	53.30	53.70	53.48	54.22	52.76	53.86	53.62	53.19	53.36	53.68	53.52	53.58
TiO2	0.21	0.24	0.23	0.15	0.24	0.20	0.23	0.19	0.17	0.16	0.21	0.23
Al2O3	0.79	0.80	0.57	0.52	0.69	0.65	0.79	0.77	0.82	0.53	0.77	0.88
Cr2O3	0.07	0.08	0.05	0.18	0.01	0.06	0.16	0.04	0.01	0.10	0.03	0.00
Fe2O3	1.10	1.58	0.86	0.99	2.71	1.27	1.45	2.68	2.29	3.10	2.30	2.21
FeO	3.70	3.19	3.16	2.35	2.55	3.35	2.53	2.24	3.67	0.99	2.91	2.64
MnO	0.04	0.13	0.10	0.08	0.14	0.14	0.10	0.09	0.12	0.09	0.13	0.13
MgO	17.12	17.09	17.38	18.19	16.79	17.19	17.74	17.28	16.33	18.15	17.00	17.18
CaO	22.32	22.83	22.63	22.88	22.99	22.88	22.47	22.90	22.99	23.33	23.00	23.04
Na2O	0.23	0.30	0.20	0.17	0.27	0.25	0.28	0.28	0.35	0.22	0.30	0.29
K20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	98.88	99.94	98.67	99.74	99.15	99.85	99.38	99.66	100.11	100.35	100.17	100.18
Cations Based on 6 Oxygens												
Si	1.969	1.964	1.976	1.975	1.950	1.971	1.964	1.951	1.958	1.948	1.956	1.955
Ti	0.006	0.007	0.006	0.004	0.007	0.005	0.006	0.005	0.005	0.004	0.006	0.006
Al	0.034	0.035	0.025	0.022	0.030	0.028	0.034	0.033	0.036	0.023	0.033	0.038
Cr	0.002	0.002	0.002	0.005	0.000	0.002	0.005	0.001	0.000	0.003	0.001	0.000
Fe3	0.031	0.044	0.024	0.027	0.075	0.035	0.040	0.074	0.063	0.085	0.063	0.061
Fe2	0.114	0.098	0.098	0.072	0.079	0.103	0.078	0.069	0.113	0.030	0.089	0.081
Mn	0.001	0.004	0.003	0.003	0.004	0.004	0.003	0.003	0.004	0.003	0.004	0.004
Mg	0.942	0.932	0.957	0.988	0.925	0.937	0.969	0.945	0.893	0.982	0.926	0.934
Ca	0.883	0.895	0.896	0.893	0.910	0.897	0.882	0.900	0.904	0.907	0.901	0.901
Na	0.017	0.021	0.014	0.012	0.019	0.018	0.020	0.020	0.025	0.015	0.021	0.021
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.603	3.599	3.667	3.729	3.594	3.624	3.650	3.614	3.530	3.707	3.586	3.598
mg	86.7	86.8	88.7	90.9	85.7	87.2	89.2	86.9	83.6	89.5	85.9	86.9
FEO*	4.69	4.61	3.94	3.25	4.99	4.49	3.84	4.65	5.73	3.78	4.98	4.63
Wo	44.8	45.5	45.4	45.1	45.8	45.5	44.8	45.3	45.8	45.3	45.5	45.6
En	47.8	47.4	48.5	49.9	46.5	47.5	49.2	47.5	45.3	49.0	46.8	47.3
Fs	7.4	7.2	6.2	5.0	7.8	7.0	6.0	7.2	8.9	5.7	7.7	7.1

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.1i

AU 26-10 Clinopyroxene Compositions

	CORE 1,1	*CORE 2,1*	*RIM 2,2*	*RIM 2,3*	*CORE 3,1*	*RIM 3,2*	*CORE 4,1*	*RIM 4,2*	*CORE 4,3*	*CORE 5,1*	*RIM 5,2*	*RIM 5,3*
SiO2	53.50	52.82	52.89	52.99	52.98	53.06	53.67	53.42	53.19	53.38	53.32	51.61
TiO2	0.20	0.20	0.24	0.35	0.17	0.20	0.24	0.16	0.08	0.21	0.15	0.27
Al2O3	1.17	1.05	1.13	1.41	0.75	0.86	1.05	1.11	0.49	0.82	0.91	1.26
Cr2O3	0.00	0.00	0.00	0.07	0.00	0.00	0.03	0.02	0.00	0.05	0.00	0.02
Fe2O3	2.29	2.86	1.27	2.28	1.53	2.10	1.16	3.26	2.49	1.71	2.35	3.63
FeO	3.79	2.96	4.49	3.40	4.17	4.17	4.13	2.87	2.43	4.15	3.09	5.44
MnO	0.15	0.14	0.08	0.15	0.17	0.15	0.14	0.19	0.18	0.12	0.11	0.23
MgO	16.69	16.84	16.27	16.81	16.48	16.47	17.04	16.52	16.84	16.79	17.02	14.10
CaO	22.53	22.34	22.08	22.71	22.28	22.38	22.21	23.20	23.61	22.30	22.56	22.48
Na2O	0.34	0.35	0.34	0.23	0.27	0.27	0.29	0.38	0.17	0.27	0.31	0.50
K20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	100.66	99.56	98.80	100.40	98.80	99.66	99.97	101.13	99.48	99.80	99.82	99.54
Cations Based on 6 Oxygens												
Si	1.950	1.944	1.963	1.936	1.967	1.956	1.964	1.941	1.959	1.962	1.955	1.931
Ti	0.006	0.005	0.007	0.010	0.005	0.006	0.006	0.004	0.002	0.006	0.004	0.008
Al	0.050	0.045	0.049	0.060	0.033	0.037	0.045	0.047	0.021	0.035	0.039	0.056
Cr	0.000	0.000	0.000	0.002	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000
Fe3	0.063	0.079	0.036	0.063	0.043	0.058	0.032	0.089	0.069	0.047	0.065	0.102
Fe2	0.115	0.091	0.139	0.104	0.130	0.129	0.126	0.087	0.075	0.128	0.095	0.170
Mn	0.005	0.004	0.002	0.005	0.005	0.005	0.004	0.006	0.006	0.004	0.003	0.007
Mg	0.907	0.924	0.900	0.916	0.912	0.905	0.929	0.895	0.924	0.920	0.930	0.787
Ca	0.880	0.881	0.878	0.889	0.886	0.884	0.871	0.903	0.932	0.878	0.886	0.902
Na	0.024	0.025	0.025	0.016	0.019	0.019	0.021	0.027	0.012	0.019	0.022	0.036
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
DS	3.492	3.523	3.493	3.503	3.543	3.509	3.540	3.505	3.650	3.535	3.562	3.268
mg	83.6	84.4	83.7	84.6	84.1	82.9	85.4	83.5	86.5	84.0	85.4	74.3
FEO*	5.85	5.53	5.64	5.45	5.55	6.06	5.18	5.80	4.67	5.69	5.20	8.71
Wo	44.8	44.6	45.0	45.1	45.0	44.7	44.5	45.7	46.6	44.5	44.9	46.0
En	46.1	46.8	46.1	46.4	46.3	45.8	47.5	45.3	46.2	46.6	47.1	40.1
Fs	9.1	8.6	9.0	8.4	8.7	9.5	8.1	8.9	7.2	8.9	8.1	13.9

Table B.1i (cont.)

AU 26-10 Clinopyroxene Compositions

	CORE 6,1	*RIM 6,2*	*RIM 6,3*
SiO2	53.84	52.87	53.91
TiO2	0.19	0.39	0.20
Al2O3	0.77	1.39	1.01
Cr2O3	0.04	0.01	0.03
Fe2O3	1.67	2.71	1.67
FeO	3.96	3.62	3.75
MnO	0.21	0.20	0.14
MgO	17.55	16.08	17.16
CaO	21.91	23.08	22.33
Na2O	0.23	0.33	0.34
K20	0.00	0.00	0.00
Total	100.37	100.68	100.54
Cations Based on 6 Oxygens			
Si	1.962	1.934	1.961
Ti	0.005	0.011	0.006
Al	0.033	0.060	0.043
Cr	0.001	0.000	0.001
Fe3	0.046	0.075	0.046
Fe2	0.121	0.111	0.114
Mn	0.006	0.006	0.004
Mg	0.954	0.876	0.931
Ca	0.856	0.904	0.870
Na	0.016	0.023	0.024
K	0.000	0.000	0.000
Total	4.000	4.000	4.000
DS	3.559	3.451	3.540
mg	85.1	82.6	85.3
FEO*	5.46	6.06	5.25
Wo	43.3	46.0	44.4
En	48.3	44.6	47.5
Fs	8.4	9.4	8.1

FEO*: Total Fe
mg=Mg/(Mg+total Fe)*100
DS(cation index)=(Si+Cr+Mg+Ca)-(Ti+Al+Fe+Mn+Na)

Table B.2a

OC7-1 Mica Phenocryst Compositions

	CORE 7,1	*CORE 7,2*	*RIM 7,5*	*RIM 7,6*	*EDGE 7,9*	*EDGE 7,10*	*CORE 6,1*	*CORE 6,2*	*CORE 6,3*	*RIM 6,4*	*RIM 6,5*	*RIM 6,6*
SiO2	40.67	39.71	39.50	40.67	37.46	37.96	40.92	39.75	41.61	41.03	40.67	41.23
TiO2	1.48	1.59	2.71	2.23	5.17	5.02	1.22	1.29	1.26	1.29	1.47	1.21
Al2O3	13.12	13.20	13.25	13.41	13.40	13.63	13.24	13.46	13.19	13.10	13.40	13.10
Cr2O3	0.36	0.40	0.11	0.19	0.04	0.00	0.67	0.59	0.75	0.63	0.69	0.65
FeO	6.48	6.97	8.95	7.91	14.18	11.25	5.32	4.93	5.32	5.20	5.78	6.44
MnO	0.05	0.00	0.04	0.01	0.12	0.01	0.03	0.03	0.00	0.04	0.05	0.05
MgO	22.09	21.45	20.03	20.68	14.79	17.41	22.37	22.83	22.90	23.19	22.16	22.64
CaO	0.00	0.00	0.01	0.04	0.05	0.03	0.00	0.01	0.00	0.04	0.02	0.00
Na2O	0.43	0.32	0.45	0.47	0.44	0.40	0.28	0.28	0.23	0.25	0.46	0.44
K2O	9.71	9.65	9.62	9.51	8.57	9.01	10.14	10.20	10.14	10.19	9.90	9.74
F	0.76	0.60	1.12	1.04	1.08	0.84	0.88	0.69	0.68	0.72	0.66	1.26
Cl	0.03	0.02	0.01	0.02	0.03	0.02	0.02	0.00	0.01	0.00	0.00	0.02
	95.18	93.91	95.80	96.18	95.33	95.58	95.09	94.06	96.09	95.68	95.26	96.78
O=F,Cl	0.33	0.26	0.47	0.44	0.46	0.36	0.38	0.29	0.29	0.30	0.28	0.54
Total	94.85	93.65	95.33	95.74	94.87	95.22	94.71	93.77	95.80	95.38	94.98	96.24

Cations Based on 23 Oxygens

	CORE 7,1	*CORE 7,2*	*RIM 7,5*	*RIM 7,6*	*EDGE 7,9*	*EDGE 7,10*	*CORE 6,1*	*CORE 6,2*	*CORE 6,3*	*RIM 6,4*	*RIM 6,5*	*RIM 6,6*
Si	6.147	6.093	6.033	6.128	5.885	5.856	6.174	6.059	6.191	6.143	6.123	6.157
Ti	0.168	0.183	0.311	0.253	0.611	0.582	0.138	0.148	0.141	0.145	0.167	0.137
Al	2.336	2.387	2.386	2.382	2.481	2.479	2.354	2.417	2.312	2.312	2.379	2.305
Cr	0.043	0.049	0.013	0.023	0.006	0.000	0.080	0.072	0.089	0.074	0.082	0.076
Fe	0.819	0.895	1.144	0.997	1.863	1.451	0.672	0.629	0.662	0.651	0.728	0.804
Mn	0.007	0.000	0.005	0.002	0.016	0.001	0.003	0.004	0.000	0.006	0.007	0.006
Mg	4.977	4.906	4.561	4.644	3.463	4.003	5.032	5.186	5.079	5.175	4.974	5.039
Ca	0.000	0.000	0.002	0.006	0.008	0.004	0.000	0.002	0.000	0.006	0.004	0.000
Na	0.126	0.097	0.132	0.137	0.135	0.119	0.083	0.082	0.065	0.071	0.165	0.127
K	1.872	1.890	1.875	1.829	1.718	1.774	1.952	1.983	1.924	1.945	1.902	1.856
F	0.362	0.293	0.542	0.495	0.539	0.412	0.422	0.334	0.322	0.339	0.313	0.595
Cl	0.007	0.004	0.004	0.005	0.008	0.005	0.004	0.000	0.002	0.000	0.001	0.905
Total	16.863	16.796	17.006	16.900	16.733	16.687	16.914	16.915	16.786	16.866	16.842	17.107
mg	85.9	84.6	80.0	82.3	65.0	73.4	88.2	89.2	88.5	88.8	87.2	86.2

Table B.2a (cont.)

OC7-1 Mica Phenocryst Compositions

	CORE 5,1	*CORE 5,2*	*CORE 5,3*	*RIM 5,4*	*RIM 5,5*	*RIM 5,6*
SiO2	39.81	41.34	40.12	41.20	40.58	40.98
TiO2	2.34	1.75	2.22	1.56	1.34	1.52
Al2O3	14.09	13.02	13.76	13.52	13.26	13.37
Cr2O3	0.03	0.07	0.07	0.59	1.51	0.81
FeO	10.64	10.13	10.27	6.07	5.01	6.11
MnO	0.05	0.10	0.14	0.00	0.04	0.08
MgO	19.07	20.57	19.23	22.22	22.52	22.37
CaO	0.00	0.00	0.00	0.02	0.02	0.00
Na2O	0.46	0.42	0.43	0.33	0.34	0.39
K2O	9.28	9.66	9.74	9.89	9.85	9.96
F	0.33	0.49	0.64	0.87	0.75	0.60
Cl	0.04	0.01	0.02	0.01	0.01	0.03
	96.14	97.56	96.64	96.28	95.23	96.22
O=F,Cl	0.15	0.21	0.27	0.37	0.32	0.26
Total	95.99	97.35	96.37	95.91	94.91	95.96

Cations Based on 23 Oxygens

	CORE 5,1	*CORE 5,2*	*CORE 5,3*	*RIM 5,4*	*RIM 5,5*	*RIM 5,6*
Si	6.03	6.17	6.07	6.15	6.11	6.12
Ti	0.27	0.20	0.25	0.18	0.15	0.17
Al	2.52	2.29	2.45	2.38	2.35	2.35
Cr	0.00	0.01	0.01	0.07	0.18	0.10
Fe	1.35	1.26	1.30	0.76	0.63	0.76
Mn	0.01	0.01	0.02	0.00	0.01	0.01
Mg	4.31	4.57	4.34	4.94	5.05	4.98
Ca	0.00	0.00	0.00	0.00	0.00	0.00
Na	0.14	0.12	0.13	0.10	0.10	0.11
K	1.79	1.84	1.88	1.88	1.89	1.90
F	0.16	0.23	0.30	0.41	0.36	0.28
Cl	0.01	0.00	0.01	0.00	0.00	0.01
Total	16.58	16.70	16.76	16.86	16.83	16.78
mg	76.2	78.3	76.9	86.7	88.9	86.7

mg=Mg/(Mg+total Fe)*100

Table B.2a

OC7-1 Mica Groundmass Compositions

	GM 1	*GM 2*	*GM 3*	*GM 4*	*GM 5*	*GM 6*	*GM 7*	*GM 8*	*GM 9*
SiO2	33.48	36.89	34.23	35.35	35.52	39.14	35.32	35.93	39.08
TiO2	6.31	6.45	6.13	5.56	6.15	6.36	6.13	6.24	6.00
Al2O3	14.19	14.27	14.16	13.82	13.90	13.90	13.70	13.87	14.67
Cr2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	13.19	13.64	13.53	14.25	15.74	15.76	15.77	17.39	14.58
MnO	0.16	0.16	0.15	0.22	0.15	0.17	0.27	0.25	0.24
MgO	14.32	14.43	14.19	14.78	13.32	13.67	13.60	12.33	13.74
CaO	0.36	0.08	0.05	0.09	0.25	0.12	0.11	0.30	0.09
Na2O	0.50	0.36	0.46	0.46	0.38	0.60	0.48	0.42	0.46
K2O	8.27	8.35	8.36	8.29	8.42	8.31	8.24	8.33	8.27
F	1.01	1.61	1.14	1.31	0.78	1.13	1.31	1.25	1.01
Cl	0.07	0.03	0.05	0.00	0.03	0.03	0.01	0.04	0.02
	91.86	96.27	92.45	94.13	94.64	99.19	94.94	96.35	98.16
O=F,Cl	0.44	0.68	0.49	0.55	0.34	0.48	0.55	0.54	0.43
Total	91.42	95.59	91.96	93.58	94.30	98.71	94.39	95.81	97.73
					Cations Based on 23 Oxygens				
Si	5.493	5.751	5.578	5.667	5.672	5.918	5.657	5.701	5.921
Ti	0.778	0.757	0.751	0.671	0.739	0.723	0.738	0.745	0.683
Al	2.743	2.622	2.720	2.611	2.616	2.476	2.587	2.594	2.619
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	1.810	1.779	1.845	1.910	2.102	1.993	2.112	2.307	1.847
Mn	0.023	0.021	0.020	0.030	0.020	0.022	0.036	0.033	0.031
Mg	3.502	3.353	3.446	3.532	3.172	3.080	3.247	2.916	3.104
Ca	0.064	0.013	0.009	0.016	0.043	0.020	0.018	0.051	0.015
Na	0.158	0.109	0.145	0.144	0.119	0.177	0.148	0.130	0.136
K	1.732	1.661	1.738	1.695	1.716	1.604	1.684	1.687	1.599
F	0.523	0.792	0.588	0.665	0.394	0.542	0.661	0.629	0.486
Cl	0.020	0.009	0.013	0.000	0.008	0.007	0.003	0.012	0.006
Total	16.845	16.868	16.853	16.941	16.601	16.561	16.892	16.806	16.446
mg	65.9	65.3	65.1	64.9	60.1	60.7	60.6	55.8	62.7

mg=Mg/(Mg+total Fe)*100

Table B.2b

OC8-16 Mica 1, Line Scan Traverse

	171	*172*	*173*	*174*	*175*	*176*	*177*	*178*	*179*	*180*	*181*	*182*
SiO2	40.41	39.06	40.38	39.63	39.82	40.17	39.89	40.59	39.93	40.06	40.02	38.70
TiO2	1.58	1.53	1.57	1.50	1.41	1.44	1.47	1.46	1.66	2.03	2.62	2.54
Al2O3	13.07	12.92	13.15	12.81	12.90	12.70	12.71	12.59	12.62	13.35	13.90	13.54
Cr2O3	0.34	0.39	0.48	0.46	0.37	0.29	0.27	0.16	0.15	0.16	0.12	0.13
FeO	9.67	6.47	6.60	6.69	7.20	7.48	7.82	8.14	8.28	8.38	9.49	9.20
MnO	0.10	0.05	0.04	0.05	0.05	0.03	0.05	0.07	0.07	0.06	0.10	0.05
MgO	21.10	22.02	22.94	22.40	22.27	22.43	21.97	22.04	21.50	19.55	20.80	20.50
CaO	0.02	0.02	0.02	0.00	0.02	0.00	0.00	0.00	0.01	0.49	0.01	0.01
Na2O	0.47	0.44	0.40	0.33	0.35	0.33	0.36	0.39	0.36	0.63	0.44	0.41
K2O	8.08	9.26	9.36	9.41	9.12	9.35	9.26	9.23	9.11	8.56	8.31	9.46
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.03	0.01
	94.85	92.19	94.96	93.30	93.53	94.22	93.83	94.72	93.73	93.30	95.83	94.54
O=F,Cl	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Total	94.84	92.18	94.95	93.29	93.53	94.22	93.82	94.71	93.72	93.29	95.82	94.53
Cations Based on 22 Oxygens												
Si	5.851	5.792	5.805	5.809	5.823	5.842	5.836	5.882	5.855	5.885	5.737	5.674
Ti	0.172	0.170	0.169	0.165	0.155	0.157	0.161	0.159	0.183	0.224	0.282	0.280
Al	2.230	2.259	2.227	2.214	2.223	2.177	2.191	2.150	2.181	2.312	2.349	2.339
Cr	0.039	0.046	0.055	0.053	0.043	0.033	0.031	0.019	0.018	0.019	0.013	0.015
Fe	1.171	0.802	0.794	0.820	0.881	0.910	0.957	0.987	1.016	1.030	1.138	1.128
Mn	0.012	0.006	0.005	0.007	0.006	0.003	0.006	0.008	0.008	0.008	0.012	0.007
Mg	4.554	4.868	4.915	4.896	4.855	4.862	4.793	4.761	4.698	4.281	4.445	4.481
Ca	0.004	0.003	0.003	0.000	0.002	0.000	0.001	0.000	0.002	0.077	0.002	0.002
Na	0.132	0.125	0.111	0.094	0.098	0.092	0.103	0.110	0.101	0.179	0.123	0.115
K	1.492	1.752	1.716	1.760	1.702	1.735	1.729	1.706	1.704	1.603	1.520	1.770
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.007	0.008	0.006	0.005	0.005	0.006	0.007	0.009	0.009	0.010	0.007	0.002
Total	15.662	15.832	15.805	15.824	15.794	15.815	15.814	15.791	15.775	15.627	15.628	15.813
mg	79.6	85.9	86.1	85.7	84.6	84.2	83.4	82.8	82.2	80.6	79.6	79.9

Table B.2b (cont.)

OC8-16 Mica 1, Line Scan Traverse

	183	*184*	*185*	*186*	*187*	*188*	*189*	*190*	*191*	*192*	*193*	*194*
SiO2	38.97	38.80	39.07	38.97	39.35	38.84	39.83	39.76	40.53	39.58	39.54	39.43
TiO2	2.63	2.59	2.56	2.58	2.65	2.33	1.63	1.62	1.72	1.67	1.60	1.62
Al2O3	13.53	13.50	13.61	13.70	13.68	13.51	12.98	13.00	13.29	13.03	12.98	12.97
Cr2O3	0.12	0.13	0.14	0.11	0.14	0.20	0.35	0.35	0.40	0.37	0.30	0.21
FeO	9.25	9.18	9.20	8.87	8.60	8.33	7.65	7.35	7.16	6.83	7.23	7.75
MnO	0.06	0.06	0.07	0.07	0.07	0.06	0.05	0.04	0.03	0.03	0.04	0.06
MgO	20.38	20.36	20.44	20.60	20.97	21.37	21.82	22.14	22.21	21.84	21.54	21.17
CaO	0.00	0.01	0.00	0.02	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Na2O	0.35	0.38	0.34	0.34	0.35	0.35	0.35	0.36	0.34	0.37	0.38	0.46
K2O	9.67	9.69	9.50	9.68	9.59	9.77	9.71	9.73	8.40	9.87	9.84	9.78
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.00	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.00	0.00	0.01	0.00
	94.96	94.72	94.95	94.96	95.43	94.77	94.38	94.37	94.07	93.58	93.45	93.46
O=F,Cl	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	94.96	94.71	94.95	94.96	95.42	94.76	94.38	94.37	94.07	93.58	93.45	93.46
Cations Based on 22 Oxygens												
Si	5.692	5.685	5.699	5.682	5.694	5.669	5.805	5.789	5.850	5.802	5.814	5.812
Ti	0.289	0.285	0.281	0.283	0.288	0.255	0.179	0.177	0.186	0.184	0.176	0.180
Al	2.329	2.332	2.339	2.354	2.333	2.324	2.230	2.230	2.262	2.251	2.249	2.253
Cr	0.014	0.015	0.016	0.013	0.016	0.023	0.040	0.040	0.045	0.043	0.035	0.025
Fe	1.130	1.124	1.123	1.081	1.041	1.017	0.932	0.895	0.864	0.837	0.889	0.956
Mn	0.007	0.008	0.009	0.009	0.008	0.007	0.006	0.005	0.004	0.004	0.005	0.007
Mg	4.436	4.446	4.445	4.478	4.524	4.650	4.740	4.805	4.778	4.772	4.723	4.651
Ca	0.000	0.002	0.000	0.002	0.003	0.000	0.000	0.003	0.000	0.000	0.000	0.000
Na	0.100	0.109	0.095	0.096	0.099	0.099	0.098	0.101	0.094	0.105	0.107	0.132
K	1.801	1.811	1.768	1.801	1.771	1.818	1.805	1.807	1.546	1.846	1.847	1.839
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.001	0.004	0.006	0.006	0.004	0.005	0.005	0.005	0.001	0.000	0.004	0.001
Total	15.799	15.820	15.780	15.805	15.781	15.867	15.838	15.858	15.631	15.843	15.848	15.855
mg	79.7	79.8	79.8	80.6	81.3	82.1	83.6	84.3	84.7	85.1	84.2	83.0

mg=Mg/(Mg+total Fe)*100

Table B.2b (cont.)
OC8-16 Mica 1, Line Scan Traverse

	195	*196*	*197*	*198*	*199*	*200*	*201*	*202*	*203*	*204*	*205*	*206*
SiO2	38.07	38.03	37.98	37.88	37.94	38.45	38.69	38.29	38.63	38.68	38.46	38.91
TiO2	2.29	2.51	2.57	2.66	2.62	2.56	2.56	2.59	2.54	2.55	2.49	2.60
Al2O3	13.52	13.42	13.59	13.46	13.46	13.66	13.59	13.49	13.48	13.52	13.38	13.56
Cr2O3	0.20	0.11	0.15	0.17	0.15	0.12	0.13	0.14	0.12	0.11	0.11	0.13
FeO	8.84	9.17	9.70	10.08	10.26	10.58	10.80	10.60	10.52	10.51	10.33	10.25
MnO	0.08	0.06	0.07	0.06	0.09	0.10	0.06	0.09	0.07	0.08	0.09	0.09
MgO	19.90	19.67	19.45	19.03	19.37	19.53	19.62	19.46	19.42	19.66	19.53	19.73
CaO	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Na2O	0.43	0.43	0.42	0.42	0.38	0.38	0.40	0.43	0.41	0.38	0.42	0.36
K2O	9.50	9.46	9.67	9.62	9.51	9.34	9.53	9.62	9.40	9.39	9.50	9.57
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.00	0.00	0.00	0.00	0.02	0.01	0.01	0.02	0.03	0.01	0.00	0.02
	92.83	92.87	93.61	93.39	93.81	94.74	95.38	94.72	94.60	94.90	94.31	95.22
O=F,Cl	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Total	92.83	92.87	93.61	93.39	93.80	94.74	95.38	94.71	94.60	94.90	94.31	95.21
Cations Based on 22 Oxygens												
Si	5.685	5.685	5.654	5.663	5.649	5.660	5.667	5.655	5.694	5.682	5.688	5.693
Ti	0.258	0.282	0.288	0.299	0.293	0.284	0.282	0.288	0.282	0.282	0.277	0.286
Al	2.379	2.364	2.385	2.371	2.362	2.371	2.346	2.347	2.342	2.342	2.333	2.338
Cr	0.023	0.013	0.018	0.020	0.017	0.014	0.015	0.016	0.014	0.013	0.013	0.015
Fe	1.104	1.146	1.207	1.261	1.278	1.303	1.323	1.309	1.297	1.292	1.278	1.254
Mn	0.010	0.007	0.008	0.008	0.011	0.012	0.007	0.011	0.009	0.010	0.011	0.011
Mg	4.429	4.383	4.317	4.242	4.299	4.287	4.283	4.284	4.268	4.305	4.305	4.304
Ca	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Na	0.124	0.125	0.122	0.122	0.110	0.109	0.112	0.122	0.117	0.109	0.121	0.103
K	1.811	1.804	1.837	1.834	1.807	1.755	1.781	1.811	1.767	1.761	1.792	1.786
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.000	0.000	0.001	0,000	0.006	0.003	0.003	0.004	0.007	0.002	0.000	0.004
Total	15.823	15.809	15.837	15.820	15.833	15.798	15.820	15.847	15.795	15.796	15.818	15.794
mg	80.0	79.3	78.1	77.1	77.1	76.7	76.4	76.6	76.7	76.9	77.1	77.4

Table B.2b (cont.)
OC8-16 Mica 1, Line Scan Traverse

	207	*208*	*209*	*210*	*211*	*212*	*213*	*214*	*215*	*216*	*217*	*218*
SiO2	38.61	38.67	39.70	38.68	38.34	49.95	40.22	40.12	40.22	40.02	39.79	39.81
TiO2	2.48	2.59	2.63	2.48	2.45	1.58	1.64	1.41	1.48	1.53	1.44	1.49
Al2O3	13.50	13.51	13.92	13.61	13.41	16.56	12.37	12.80	12.08	12.22	12.65	12.57
Cr2O3	0.09	0.15	0.12	0.11	0.12	0.05	0.15	0.18	0.12	0.21	0.25	0.28
FeO	10.12	10.01	10.24	9.69	9.48	5.95	8.48	8.20	7.78	7.63	7.43	7.11
MnO	0.10	0.09	0.08	0.07	0.07	0.04	0.05	0.05	0.04	0.03	0.05	0.05
MgO	19.66	19.90	20.08	19.93	20.03	11.62	21.47	21.77	22.06	22.19	21.99	22.43
CaO	0.00	0.00	0.00	0.02	0.01	1.37	0.02	0.00	0.00	0.00	0.01	0.00
Na2O	0.35	0.36	0.35	0.37	0.34	0.91	0.37	0.33	0.35	0.34	0.31	0.31
K2O	9.55	9.55	8.42	9.59	9.70	7.38	9.87	9.88	9.78	9.81	9.92	9.90
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.02	0.00	0.02	0.02	0.02	0.20	0.01	0.02	0.01	0.03	0.02	0.03
	94.49	94.82	95.56	94.56	93.95	95.60	94.64	94.74	93.92	94.01	93.84	93.96
O=F,Cl	0.01	0.00	0.00	0.00	0.01	0.05	0.00	0.00	0.00	0.01	0.00	0.01
Total	94.49	94.82	95.56	94.56	93.95	95.56	94.64	94.74	93.91	94.00	93.84	93.96
Cations Based on 22 Oxygens												
Si	5.693	5.678	5.732	5.686	5.677	6.825	5.870	5.838	5.892	5.859	5.833	5.822
Ti	0.275	0.286	0.286	0.274	0.273	0.162	0.179	0.155	0.163	0.169	0.159	0.163
Al	2.346	2.338	2.369	2.359	2.340	2.667	2.127	2.195	2.086	2.108	2.185	2.166
Cr	0.011	0.017	0.014	0.013	0.014	0.006	0.017	0.021	0.014	0.024	0.029	0.033
Fe	1.248	1.229	1.237	1.191	1.174	0.680	1.035	0.998	0.953	0.935	0.911	0.869
Mn	0.013	0.011	0.009	0.008	0.008	0.004	0.006	0.006	0.005	0.004	0.006	0.006
Mg	4.321	4.355	4.322	4.368	4.421	2.368	4.670	4.723	4.818	4.844	4.807	4.890
Ca	0.000	0.000	0.000	0.003	0.001	0.200	0.003	0.000	0.000	0.000	0.001	0.000
Na	0.099	0.101	0.097	0.105	0.097	0.240	0.105	0.093	0.099	0.097	0.089	0.088
K	1.796	1.788	1.551	1.798	1.833	1.286	1.837	1.834	1.829	1.833	1.855	1.847
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.006	0.000	0.004	0.004	0.006	0.047	0.003	0.004	0.002	0.007	0.005	0.007
Total	15.807	15.804	15.619	15.810	15.844	14.486	15.853	15.867	15.861	15.878	15.878	15.890
mg	77.6	78.0	77.8	78.6	79.0	77.7	81.9	82.6	83.5	83.8	84.1	84.9

mg=Mg/(Mg+total Fe)*100

Table B.2b (cont.)

OC8-16 Mica 1, Line Scan Traverse

	219	*220*	*221*	*222*	*223*	*224*	*225*	*226*	*227*	*228*
SiO2	41.27	39.85	40.19	40.34	40.11	39.90	40.07	40.01	39.31	38.11
TiO2	1.41	1.51	1.44	1.51	1.52	1.47	1.49	1.36	1.39	1.52
Al2O3	12.88	12.79	12.92	12.83	12.80	12.82	12.80	12.88	12.31	12.12
Cr2O3	0.43	0.41	0.44	0.45	0.48	0.51	0.58	0.68	0.70	0.64
FeO	7.17	6.63	6.48	6.29	6.11	6.27	6.35	5.99	6.12	11.66
MnO	0.04	0.04	0.03	0.03	0.04	0.02	0.05	0.03	0.02	0.11
MgO	21.95	21.70	21.71	21.93	21.75	21.64	21.72	21.87	21.31	17.58
CaO	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02
Na2O	0.33	0.32	0.34	0.32	0.38	0.38	0.41	0.42	0.43	0.48
K2O	8.36	9.77	9.68	9.69	9.72	9.67	9.57	9.77	9.70	9.09
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.01	0.02	0.02	0.00	0.02	0.00	0.02	0.01	0.02	0.03
	93.85	93.03	93.23	93.39	92.90	92.68	93.05	93.02	91.30	91.35
O=F,Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Total	93.85	93.02	93.22	93.39	92.90	92.68	93.05	93.02	91.30	91.34
					Cations Based on 22 Oxygens					
Si	5.960	5.863	5.887	5.892	5.890	5.877	5.880	5.871	5.891	5.862
Ti	0.154	0.168	0.158	0.166	0.168	0.163	0.164	0.150	0.157	0.176
Al	2.191	2.218	2.230	2.208	2.215	2.227	2.214	2.229	2.174	2.197
Cr	0.049	0.047	0.051	0.052	0.055	0.059	0.067	0.079	0.083	0.078
Fe	0.865	0.815	0.793	0.768	0.750	0.772	0.780	0.735	0.767	1.500
Mn	0.005	0.005	0.004	0.004	0.004	0.003	0.007	0.004	0.002	0.015
Mg	4.726	4.759	4.740	4.775	4.761	4.752	4.751	4.784	4.760	4.031
Ca	0.002	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.003
Na	0.092	0.090	0.095	0.092	0.107	0.107	0.116	0.119	0.126	0.144
K	1.539	1.833	1.809	1.805	1.821	1.817	1.792	1.829	1.854	1.783
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.003	0.005	0.005	0.001	0.004	0.001	0.006	0.003	0.004	0.008
Total	15.585	15.803	15.771	15.762	15.776	15.780	15.775	15.803	15.818	15.796
mg	84.5	85.4	85.7	86.1	86.4	86.0	85.9	86.7	86.1	72.9

mg=Mg/(Mg+total Fe)*100

Table B.2b

OC8-16 Mica 2, Line Scan Traverse

	81	*82*	*83*	*84*	*85*	*86*	*87*	*88*	*89*	*90*	*91*	*92*
SiO2	39.55	39.25	39.97	39.64	39.91	39.96	39.99	40.18	39.98	39.55	40.87	39.92
TiO2	4.11	1.83	1.57	1.86	1.77	1.64	1.82	1.68	1.75	1.88	2.20	1.93
Al2O3	12.35	12.38	12.84	13.09	13.22	13.10	13.30	12.83	12.92	13.10	13.84	13.09
Cr2O3	0.01	0.16	0.21	0.13	0.10	0.12	0.12	0.09	0.11	0.05	0.05	0.09
FeO	13.83	11.57	9.96	8.67	7.92	7.69	8.01	7.76	8.12	8.22	9.26	9.00
MnO	0.21	0.08	0.07	0.04	0.05	0.02	0.03	0.03	0.02	0.02	0.04	0.03
MgO	12.67	19.14	20.59	20.92	21.42	21.80	21.56	21.68	21.42	20.94	21.57	21.25
CaO	2.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02
Na2O	0.67	0.52	0.48	0.47	0.46	0.41	0.44	0.38	0.42	0.38	0.38	0.39
K2O	8.73	9.43	9.35	9.48	9.49	9.63	9.62	9.54	9.56	9.40	8.35	9.45
F	0.03	1.08	1.05	0.70	0.56	0.32	0.16	0.05	0.07	0.00	0.00	0.00
Cl	0.06	0.05	0.01	0.01	0.05	0.01	0.03	0.01	0.02	0.02	0.04	0.02
	94.29	95.51	96.11	95.01	94.94	94.69	95.07	94.25	94.39	93.56	96.63	95.19
O=F,Cl	0.03	0.47	0.44	0.30	0.25	0.14	0.07	0.02	0.03	0.01	0.01	0.00
Total	94.27	95.04	95.67	94.71	94.70	94.55	94.99	94.22	94.36	93.55	96.62	95.18
Cations Based on 22 Oxygens												
Si	5.952	5.828	5.832	5.801	5.812	5.815	5.796	5.855	5.832	5.816	5.792	5.791
Ti	0.465	0.205	0.173	0.205	0.194	0.180	0.198	0.185	0.192	0.208	0.234	0.210
Al	2.190	2.167	2.209	2.258	2.270	2.247	2.272	2.203	2.221	2.270	2.313	2.239
Cr	0.001	0.019	0.024	0.015	0.012	0.014	0.013	0.011	0.013	0.006	0.006	0.010
Fe	1.740	1.436	1.215	1.061	0.964	0.936	0.971	0.946	0.991	1.011	1.098	1.092
Mn	0.027	0.010	0.009	0.004	0.006	0.003	0.004	0.004	0.003	0.002	0.005	0.003
Mg	2.842	4.237	4.479	4.563	4.650	4.729	4.658	4.709	4.659	4.591	4.558	4.596
Ca	0.334	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.003
Na	0.196	0.149	0.136	0.133	0.131	0.115	0.125	0.109	0.118	0.109	0.103	0.111
K	1.676	1.787	1.741	1.770	1.763	1.789	1.778	1.774	1.779	1.764	1.509	1.750
F	0.015	0.508	0.483	0.326	0.256	0.145	0.072	0.024	0.030	0.000	0.000	0.000
Cl	0.016	0.011	0.002	0.003	0.013	0.003	0.008	0.002	0.004	0.006	0.010	0.005
Total	15.455	16.361	16.302	16.137	16.069	15.975	15.895	15.820	15.842	15.781	15.631	15.810
mg	62.0	74.7	78.7	81.1	82.8	83.5	82.8	83.3	82.5	82.0	80.6	80.8

Table B.2b (cont.)

OC8-16 Mica 2, Line Scan Traverse

	93	*94*	*95*	*96*	*97*	*98*	*99*	*100*	*101*	*102*	*103*	*104*
SiO2	40.25	40.25	39.20	38.83	39.11	39.01	39.19	38.93	39.76	39.02	39.04	38.66
TiO2	1.60	1.71	2.25	2.42	2.48	2.34	2.44	2.38	2.51	2.38	2.19	2.29
Al2O3	12.80	12.47	13.65	13.70	13.81	13.52	13.77	13.53	13.68	13.36	13.20	13.44
Cr2O3	0.13	0.12	0.15	0.10	0.12	0.11	0.11	0.12	0.16	0.11	0.11	0.16
FeO	8.74	8.82	9.68	9.96	9.93	9.99	10.08	10.07	10.62	10.51	10.52	10.75
MnO	0.04	0.05	0.07	0.07	0.08	0.06	0.06	0.08	0.05	0.05	0.04	0.06
MgO	21.42	21.11	20.26	19.98	20.05	19.76	19.91	19.66	20.00	19.73	19.96	19.66
CaO	0.03	0.02	0.04	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.01
Na2O	0.40	0.44	0.40	0.41	0.40	0.37	0.45	0.40	0.42	0.42	0.44	0.45
K2O	9.40	9.46	9.32	9.26	9.36	9.00	9.28	9.29	8.43	9.44	9.64	9.51
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.02	0.02	0.03	0.03	0.02	0.04	0.02	0.03	0.03	0.00	0.02	0.01
	94.83	94.47	95.03	94.80	95.38	94.22	95.33	94.51	95.70	95.06	95.20	94.99
O=F,Cl	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00
Total	94.83	94.46	95.02	94.80	95.38	94.21	95.33	94.50	95.69	95.06	95.19	94.99
Cations Based on 22 Oxygens												
Si	5.850	5.878	5.719	5.689	5.692	5.738	5.708	5.724	5.746	5.719	5.723	5.687
Ti	0.175	0.188	0.247	0.267	0.272	0.259	0.267	0.263	0.273	0.263	0.242	0.253
Al	2.192	2.147	2.347	2.366	2.370	2.344	2.364	2.345	2.331	2.309	2.281	2.330
Cr	0.015	0.014	0.018	0.012	0.014	0.013	0.013	0.014	0.019	0.013	0.013	0.018
Fe	1.062	1.078	1.181	1.220	1.209	1.229	1.228	1.238	1.283	1.289	1.291	1.322
Mn	0.005	0.006	0.008	0.009	0.010	0.008	0.008	0.010	0.006	0.007	0.006	0.007
Mg	4.640	4.596	4.405	4.363	4.350	4.333	4.322	4.308	4.309	4.311	4.363	4.312
Ca	0.005	0.004	0.006	0.006	0.005	0.004	0.003	0.005	0.004	0.004	0.005	0.001
Na	0.112	0.124	0.112	0.117	0.112	0.104	0.126	0.113	0.117	0.120	0.125	0.128
K	1.743	1.762	1.734	1.730	1.738	1.690	1.724	1.743	1.554	1.766	1.803	1.785
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.004	0.005	0.008	0.008	0.004	0.010	0.005	0.007	0.008	0.001	0.005	0.003
Total	15.804	15.801	15.784	15.786	15.774	15.731	15.767	15.768	15.649	15.801	15.856	15.845
mg	81.4	81.0	78.9	78.1	78.3	77.9	77.9	77.7	77.1	77.0	77.2	76.5

mg=Mg/(Mg+total Fe)*100

Table B.2b (cont.)

OC8-16 Mica 2, Line Scan Traverse

	105	*106*	*107*	*108*	*109*	*110*	*111*	*112*	*113*	*114*	*115*	*116*
SiO2	38.86	38.60	38.97	38.69	38.88	39.23	40.71	40.30	39.13	38.85	39.22	39.16
TiO2	2.29	2.23	2.28	2.23	2.30	2.23	2.24	2.15	2.32	2.22	2.20	2.15
Al2O3	13.63	13.25	13.58	13.21	13.27	13.15	13.26	12.96	13.17	13.39	13.15	13.04
Cr2O3	0.15	0.16	0.16	0.14	0.18	0.10	0.15	0.20	0.21	0.20	0.16	0.18
FeO	10.61	10.51	10.72	10.77	10.54	10.45	10.79	10.31	10.54	10.64	10.50	10.31
MnO	0.08	0.05	0.05	0.05	0.05	0.06	0.08	0.07	0.07	0.08	0.07	0.07
MgO	19.86	19.85	19.78	19.59	19.86	19.89	19.98	19.93	19.28	19.29	19.70	19.50
CaO	0.03	0.04	0.03	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Na2O	0.46	0.42	0.44	0.44	0.44	0.45	0.45	0.47	0.43	0.46	0.42	0.46
K2O	9.28	9.39	9.36	9.47	9.40	9.42	7.92	9.35	9.35	9.24	9.19	9.36
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.02	0.01	0.02	0.03	0.01	0.03	0.01	0.02	0.02	0.01	0.03	0.03
	95.26	94.51	95.39	94.64	94.93	95.04	95.59	95.76	94.51	94.40	94.63	94.25
O=F,Cl	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01
Total	95.26	94.51	95.38	94.63	94.93	95.03	95.59	95.75	94.50	94.39	94.62	94.24
Cations Based on 22 Oxygens												
Si	5.686	5.698	5.697	5.713	5.711	5.749	5.862	5.841	5.767	5.735	5.765	5.783
Ti	0.252	0.248	0.251	0.248	0.254	0.245	0.243	0.235	0.257	0.247	0.243	0.239
Al	2.350	2.305	2.340	2.299	2.297	2.273	2.250	2.214	2.289	2.330	2.278	2.269
Cr	0.017	0.018	0.019	0.016	0.021	0.012	0.017	0.023	0.024	0.024	0.019	0.021
Fe	1.299	1.297	1.310	1.330	1.294	1.281	1.300	1.250	1.300	1.314	1.291	1.273
Mn	0.010	0.007	0.006	0.006	0.007	0.008	0.010	0.008	0.009	0.010	0.009	0.009
Mg	4.330	4.367	4.311	4.312	4.348	4.345	4.289	4.306	4.237	4.245	4.317	4.293
Ca	0.004	0.006	0.005	0.001	0.001	0.005	0.000	0.000	0.000	0.000	0.000	0.000
Na	0.129	0.121	0.125	0.126	0.126	0.128	0.127	0.133	0.122	0.133	0.120	0.132
K	1.732	1.768	1.745	1.784	1.761	1.762	1.455	1.729	1.758	1.741	1.724	1.763
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.006	0.004	0.005	0.008	0.002	0.007	0.003	0.005	0.004	0.004	0.007	0.007
Total	15.814	15.840	15.813	15.844	15.822	15.815	15.554	15.743	15.764	15.782	15.772	15.788
mg	76.9	77.1	76.7	76.4	77.1	77.2	76.7	77.5	76.5	76.4	77.0	77.1

Table B.2b (cont.)

OC8-16 Mica 2, Line Scan Traverse

	117	*118*	*119*	*120*	*121*	*122*	*123*	*124*	*125*	*126*	*127*	*128*
SiO2	39.08	38.46	38.39	38.80	40.20	39.76	39.03	39.07	38.46	38.53	39.60	39.54
TiO2	2.10	2.28	2.17	2.18	2.12	2.14	2.08	2.09	2.18	2.23	2.15	2.07
Al2O3	13.30	13.73	13.62	13.57	13.53	13.19	13.00	13.28	13.51	13.62	13.47	13.15
Cr2O3	0.25	0.27	0.26	0.25	0.16	0.21	0.16	0.18	0.23	0.23	0.20	0.24
FeO	10.69	10.71	10.92	10.82	10.81	10.59	10.55	10.62	10.76	10.80	10.67	10.42
MnO	0.06	0.08	0.09	0.05	0.06	0.06	0.06	0.10	0.06	0.07	0.07	0.06
MgO	19.39	18.96	19.09	19.18	20.25	20.02	19.51	19.60	19.46	19.46	19.82	19.81
CaO	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02
Na2O	0.46	0.47	0.45	0.45	0.43	0.47	0.46	0.49	0.45	0.41	0.49	0.48
K2O	9.30	9.29	9.28	9.18	8.09	9.19	9.19	9.25	9.10	9.20	9.09	9.25
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.03	0.01	0.02	0.03	0.01	0.03	0.02	0.03	0.01	0.01	0.02	0.02
	94.65	94.25	94.29	94.51	95.66	95.65	94.06	94.72	94.19	94.56	95.57	95.05
O=F,Cl	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Total	94.65	94.25	94.29	94.50	95.66	95.65	94.06	94.71	94.19	94.56	95.56	95.04
Cations Based on 22 Oxygens												
Si	5.754	5.694	5.689	5.723	5.797	5.779	5.777	5.748	5.692	5.684	5.759	5.784
Ti	0.233	0.253	0.242	0.242	0.230	0.234	0.232	0.231	0.242	0.247	0.235	0.227
Al	2.308	2.396	2.379	2.359	2.300	2.259	2.268	2.303	2.358	2.368	2.310	2.267
Cr	0.030	0.032	0.031	0.030	0.019	0.024	0.019	0.021	0.027	0.027	0.023	0.028
Fe	1.317	1.326	1.354	1.335	1.303	1.287	1.305	1.307	1.332	1.333	1.298	1.274
Mn	0.007	0.010	0.012	0.007	0.008	0.007	0.008	0.012	0.007	0.008	0.009	0.007
Mg	4.256	4.184	4.216	4.217	4.353	4.337	4.305	4.299	4.293	4.280	4.296	4.320
Ca	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.003
Na	0.133	0.136	0.129	0.129	0.120	0.132	0.132	0.140	0.128	0.117	0.137	0.137
K	1.747	1.754	1.755	1.727	1.487	1.704	1.735	1.735	1.718	1.731	1.686	1.726
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.006	0.002	0.005	0.006	0.003	0.006	0.004	0.008	0.001	0.003	0.004	0.005
Total	15.790	15.787	15.811	15.775	15.620	15.770	15.785	15.804	15.797	15.799	15.756	15.778
mg	76.4	75.9	75.7	76.0	77.0	77.1	76.7	76.7	76.3	76.3	76.8	77.2

mg=Mg/(Mg+total Fe)*100

Table B.2b (cont.)

OC8-16 Mica 2, Line Scan Traverse

	129	*130*	*131*	*132*	*133*	*134*	*135*	*136*	*137*	*138*	*139*	*140*
SiO2	39.46	39.72	39.49	39.55	39.78	39.97	40.42	40.42	39.50	38.11	39.20	38.99
TiO2	1.91	1.89	1.83	2.11	1.81	1.92	1.65	1.30	1.86	2.32	2.42	2.02
Al2O3	13.22	13.24	11.89	13.08	12.52	12.75	12.28	10.44	12.18	13.23	12.67	12.51
Cr2O3	0.22	0.26	0.23	0.21	0.26	0.29	0.25	0.17	0.25	0.28	0.23	0.21
FeO	10.43	10.38	10.50	10.56	10.09	10.04	10.40	10.42	10.56	11.11	11.39	10.59
MnO	0.08	0.08	0.06	0.07	0.07	0.07	0.04	0.05	0.07	0.09	0.07	0.07
MgO	19.76	19.90	19.69	20.03	20.42	20.59	20.92	20.74	20.18	19.21	19.58	20.01
CaO	0.02	0.01	0.18	0.10	0.06	0.02	0.12	0.38	0.11	0.04	0.15	0.22
Na2O	0.43	0.49	0.40	0.50	0.53	0.51	0.50	0.36	0.44	0.52	0.40	0.44
K2O	9.20	9.26	8.20	8.35	8.99	9.26	8.78	6.25	8.81	9.23	7.15	8.83
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.01	0.02	0.05	0.05	0.02	0.01	0.05	0.04	0.03	0.04	0.06	0.04
	94.74	95.23	92.53	94.62	94.54	95.43	95.40	90.56	93.98	94.17	93.32	93.92
O=F,Cl	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Total	94.74	95.23	92.52	94.60	94.53	95.43	95.39	90.55	93.98	94.16	93.31	93.91
Cations Based on 22 Oxygens												
Si	5.788	5.795	5.909	5.788	5.836	5.812	5.872	6.097	5.841	5.670	5.804	5.780
Ti	0.210	0.208	0.206	0.233	0.200	0.210	0.180	0.148	0.207	0.260	0.269	0.225
Al	2.286	2.277	2.097	2.256	2.164	2.185	2.103	1.855	2.124	2.321	2.211	2.185
Cr	0.025	0.030	0.027	0.024	0.030	0.033	0.028	0.020	0.029	0.033	0.027	0.024
Fe	1.280	1.267	1.313	1.293	1.237	1.221	1.263	1.314	1.306	1.383	1.411	1.313
Mn	0.010	0.010	0.008	0.009	0.009	0.008	0.005	0.006	0.008	0.011	0.009	0.009
Mg	4.321	4.327	4.392	4.370	4.465	4.464	4.530	4.663	4.449	4.260	4.321	4.422
Ca	0.004	0.001	0.029	0.015	0.009	0.004	0.018	0.061	0.017	0.006	0.024	0.035
Na	0.123	0.138	0.117	0.143	0.151	0.145	0.141	0.104	0.127	0.149	0.116	0.126
K	1.721	1.724	1.566	1.559	1.683	1.718	1.628	1.203	1.662	1.752	1.350	1.669
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.002	0.005	0.013	0.013	0.006	0.004	0.012	0.011	0.008	0.009	0.015	0.010
Total	15.771	15.780	15.678	15.704	15.790	15,803	15.779	15.482	15.777	15.853	15.555	15.798
mg	77.1	77.4	77.0	77.2	78.3	78.5	78.2	78.0	77.3	75.5	75.4	77.1

Table B.2b (cont.)

OC8-16 Mica 2, Line Scan Traverse

	141	*142*	*143*	*144*	*145*	*146*	*147*	*148*	*149*	*150*	*151*	*152*
SiO2	40.44	39.15	39.43	39.08	39.75	38.77	39.01	38.76	39.02	39.06	40.07	39.24
TiO2	2.04	1.99	2.15	2.08	2.12	2.24	2.32	2.36	2.33	2.38	2.37	2.24
Al2O3	13.23	13.27	13.08	13.01	13.18	13.37	13.57	13.51	13.61	13.56	13.24	13.24
Cr2O3	0.19	0.14	0.17	0.10	0.17	0.15	0.16	0.13	0.11	0.13	0.12	0.12
FeO	10.62	10.31	10.33	10.38	10.30	10.57	10.30	10.31	10.20	10.15	10.00	9.83
MnO	0.09	0.08	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.04	0.05	0.03
MgO	20.07	20.16	20.02	19.88	20.22	19.73	19.71	19.78	19.96	19.94	20.46	20.31
CaO	0.02	0.01	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.03	0.01
Na2O	0.44	0.42	0.45	0.45	0.47	0.46	0.44	0.45	0.43	0.43	0.42	0.42
K2O	8.06	9.40	9.25	9.55	9.45	9.45	9.21	9.46	9.56	9.46	8.08	9.26
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.03	0.03	0.02	0.04	0.03	0.03	0.02	0.02	0.03	0.04	0.01	0.01
	95.23	94.96	94.98	94.67	95.76	94.84	94.82	94.85	95.31	95.20	94.84	94.71
O=F,Cl	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00
Total	95.22	94.96	94.97	94.66	95.75	94.83	94.82	94.84	95.30	95.20	94.84	94.70
Cations Based on 22 Oxygens												
Si	5.852	5.739	5.772	5.757	5.772	5.706	5.720	5.694	5.701	5.708	5.809	5.746
Ti	0.222	0.220	0.237	0.230	0.232	0.248	0.256	0.261	0.256	0.262	0.259	0.246
Al	2.257	2.293	2.257	2.260	2.256	2.319	2.344	2.340	2.343	2.335	2.262	2.285
Cr	0.022	0.016	0.019	0.011	0.019	0.018	0.019	0.015	0.013	0.015	0.014	0.013
Fe	1.285	1.264	1.265	1.279	1.251	1.301	1.263	1.267	1.247	1.241	1.213	1.204
Mn	0.011	0.010	0.008	0.009	0.007	0.008	0.007	0.008	0.008	0.005	0.006	0.004
Mg	4.329	4.406	4.368	4.366	4.378	4.328	4.308	4.333	4.347	4.343	4.422	4.433
Ca	0.004	0.001	0.002	0.003	0.001	0.001	0.002	0.000	0.000	0.002	0.004	0.002
Na	0.124	0.118	0.128	0.129	0.134	0.130	0.125	0.128	0.121	0.122	0.117	0.118
K	1.488	1.758	1.727	1.795	1.751	1.774	1.723	1.774	1.783	1.764	1.494	1.730
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.008	0.007	0.006	0.011	0.006	0.008	0.006	0.005	0.008	0.009	0.003	0.003
Total	15.601	15.832	15.787	15.851	15.807	15.839	15.773	15.823	15.825	15.807	15.602	15.785
mg	77.1	77.7	77.5	77.3	77.8	76.9	77.3	77.4	77.7	77.8	78.5	78.6

mg=Mg/(Mg+total Fe)*100

Table B.2b (cont.)

OC8-16 Mica 2, Line Scan Traverse

	153	*154*	*155*	*156*	*157*	*158*	*159*	*160*	*161*	*162*	*163*	*164*
SiO2	39.07	38.93	40.33	40.45	39.29	40.06	39.98	40.00	40.67	39.60	39.66	39.78
TiO2	2.35	2.39	1.76	1.70	2.05	1.94	1.81	1.76	1.87	1.84	1.80	1.85
Al2O3	13.44	13.21	12.91	13.04	13.28	13.45	13.31	13.09	13.26	13.09	13.14	13.18
Cr2O3	0.14	0.11	0.11	0.11	0.07	0.07	0.08	0.06	0.13	0.10	0.11	0.13
FeO	9.67	9.51	9.15	8.83	9.05	8.79	8.48	8.31	8.83	7.99	7.99	8.01
MnO	0.05	0.05	0.04	0.03	0.02	0.04	0.02	0.03	0.06	0.04	0.05	0.04
MgO	20.08	20.24	21.26	21.69	20.96	21.13	21.51	21.62	21.11	21.19	21.07	21.19
CaO	0.02	0.03	0.03	0.03	0.01	0.02	0.01	0.01	0.02	0.03	0.02	0.03
Na2O	0.41	0.37	0.43	0.43	0.42	0.43	0.36	0.38	0.40	0.42	0.44	0.41
K2O	9.44	9.37	9.42	9.41	9.47	9.40	9.55	9.65	8.06	9.42	9.45	9.48
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.03	0.03	0.00	0.01	0.02	0.02	0.01	0.01	0.03	0.02	0.03	0.05
	94.69	94.23	95.42	95.73	94.64	95.34	95.11	94.91	94.42	93.73	93.76	94.15
O=F,Cl	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
Total	94.69	94.22	95.42	95.72	94.63	95.33	95.11	94.90	94.41	93.73	93.76	94.14
Cations Based on 22 Oxygens												
Si	5.726	5.730	5.834	5.822	5.743	5.791	5.790	5.805	5.880	5.809	5.816	5.812
Ti	0.259	0.264	0.192	0.184	0.225	0.210	0.197	0.192	0.203	0.203	0.199	0.204
Al	2.322	2.292	2.201	2.213	2.287	2.292	2.271	2.240	2.259	2.263	2.272	2.270
Cr	0.017	0.013	0.013	0.012	0.008	0.008	0.009	0.007	0.015	0.012	0.013	0.015
Fe	1.185	1.170	1.107	1.063	1.106	1.063	1.027	1.009	1.067	0.980	0.980	0.978
Mn	0.007	0.006	0.004	0.003	0.003	0.005	0.003	0.003	0.007	0.005	0.007	0.005
Mg	4.387	4.442	4.584	4.655	4.567	4.552	4.642	4.677	4.548	4.634	4.606	4.614
Ca	0.003	0.004	0.004	0.004	0.002	0.003	0.002	0.002	0.003	0.005	0.003	0.004
Na	0.117	0.106	0.120	0.120	0.119	0.120	0.101	0.107	0.112	0.120	0.126	0.116
K	1.765	1.759	1.738	1.727	1.766	1.733	1.764	1.786	1.486	1.762	1.769	1.767
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.007	0.007	0.001	0.003	0.004	0.004	0.003	0.002	0.008	0.006	0.007	0.013
Total	15.793	15.792	15.797	15.808	15.831	15.780	15.810	15.828	15.587	15.798	15.796	15.797
mg	78.7	79.1	80.6	81.4	80.5	81.1	81.9	82.3	81.0	82.5	82.5	82.5

Table B.2b (cont.)

OC8-16 Mica 2, Line Scan Traverse

	165	*166*	*167*	*168*	*169*	*170*
SiO2	39.60	39.58	39.48	39.09	38.07	55.43
TiO2	1.75	1.87	1.72	1.75	2.73	1.32
Al2O3	12.90	13.15	12.89	12.70	12.14	15.59
Cr2O3	0.16	0.15	0.21	0.24	0.08	0.00
FeO	7.88	8.25	9.11	10.89	12.58	5.98
MnO	0.06	0.02	0.09	0.10	0.11	0.07
MgO	20.98	21.15	20.54	19.63	17.76	6.49
CaO	0.04	0.01	0.03	0.04	0.05	1.21
Na2O	0.40	0.44	0.45	0.51	0.53	2.52
K2O	9.43	9.46	9.30	9.21	9.14	8.31
F	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.04	0.04	0.03	0.02	0.04	0.05
	93.25	94.12	93.85	94.17	93.21	96.95
O=F,Cl	0.01	0.01	0.01	0.00	0.01	0.01
Total	93.24	94.11	93.84	94.17	93.20	96.94
Cations Based on 22 Oxygens						
Si	5.839	5.793	5.817	5.795	5.765	7.428
Ti	0.194	0.205	0.191	0.195	0.311	0.133
Al	2.242	2.269	2.240	2.219	2.167	2.462
Cr	0.019	0.018	0.024	0.028	0.009	0.000
Fe	0.972	1.009	1.123	1.350	1.593	0.670
Mn	0.007	0.003	0.011	0.012	0.014	0.008
Mg	4.612	4.615	4.511	4.338	4.009	1.296
Ca	0.006	0.001	0.005	0.006	0.008	0.173
Na	0.114	0.125	0.127	0.148	0.156	0.655
K	1.775	1.766	1.749	1.742	1.766	1.420
F	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.010	0.011	0.008	0.006	0.011	0.011
Total	15.791	15.815	15.806	15.837	15.807	14.257
mg	82.6	82.1	80.1	76.3	71.6	65.9

mg=Mg/(Mg+total Fe)*100

Table B.2c

DAT4-5 Mica Compositions

	CORE 1,1	*CORE 1,2*	*RIM 1,3*	*RIM 1,4*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*CORE 3,2*	*MID 3,3*	*MID 3,4*
SiO2	38.62	38.31	38.86	39.12	39.01	39.42	39.70	39.66	39.57	39.65	39.27	39.04
TiO2	1.49	1.49	1.44	1.48	1.37	1.35	1.35	1.65	1.49	1.42	1.42	1.48
Al2O3	12.23	11.94	11.66	11.98	12.02	11.91	11.80	12.34	11.70	11.59	11.76	11.70
Cr2O3	0.01	0.06	0.10	0.09	0.15	0.12	0.17	0.26	0.06	0.06	0.10	0.09
FeO	8.36	8.13	8.16	7.89	7.92	7.97	7.32	8.05	7.62	7.47	7.60	7.55
MnO	0.03	0.07	0.09	0.08	0.00	0.05	0.07	0.03	0.01	0.01	0.05	0.00
MgO	21.78	22.17	22.16	22.22	22.65	22.76	22.16	22.36	22.40	22.79	22.72	22.55
CaO	0.00	0.04	0.05	0.08	0.00	0.00	0.00	0.15	0.03	0.00	0.00	0.00
Na2O	0.34	0.26	0.34	0.34	0.31	0.28	0.30	0.35	0.20	0.29	0.23	0.28
K2O	9.91	10.00	9.87	10.01	10.41	10.44	10.10	10.11	10.22	10.26	10.27	10.27
F	0.61	0.86	0.57	0.64	0.71	0.60	0.79	0.60	0.54	0.79	0.43	0.72
Cl	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00
	93.38	93.33	93.30	93.95	94.56	94.90	93.76	95.58	93.84	94.33	93.85	93.68
O=F,Cl	0.26	0.36	0.24	0.27	0.30	0.25	0.33	0.26	0.23	0.33	0.18	0.30
Total	93.12	92.97	93.06	93.68	94.26	94.65	93.43	95.32	93.61	94.00	93.67	93.38
Cations Based on 23 Oxygens												
Si	6.033	6.010	6.070	6.065	6.028	6.060	6.152	6.043	6.124	6.119	6.078	6.074
Ti	0.175	0.175	0.170	0.172	0.160	0.156	0.157	0.189	0.173	0.165	0.165	0.173
Al	2.251	2.208	2.147	2.190	2.189	2.157	2.155	2.216	2.133	2.107	2.145	2.145
Cr	0.001	0.007	0.013	0.011	0.019	0.015	0.020	0.031	0.007	0.007	0.012	0.011
Fe	1.093	1.066	1.066	1.023	1.023	1.025	0.949	1.025	0.986	0.964	0.984	0.982
Mn	0.004	0.010	0.012	0.010	0.000	0.007	0.010	0.004	0.002	0.002	0.007	0.000
Mg	5.071	5.184	5.160	5.135	5.217	5.214	5.118	5.078	5.165	5.242	5.241	5.228
Ca	0.000	0.007	0.009	0.014	0.000	0.000	0.000	0.025	0.005	0.000	0.000	0.000
Na	0.103	0.078	0.104	0.103	0.093	0.082	0.089	0.103	0.062	0.088	0.069	0.085
K	1.975	2.001	1.967	1.980	2.052	2.046	1.996	1.965	2.017	2.020	2.027	2.037
F	0.300	0.426	0.283	0.315	0.348	0.294	0.388	0.291	0.264	0.384	0.212	0.354
Cl	0.000	0.000	0.000	0.005	0.002	0.000	0.001	0.006	0.000	0.000	0.000	0.000
Total	17.005	17.172	17.000	17.024	17.131	17.057	17.034	16.976	16.937	17.098	16.939	17.090
mg	82.3	82.9	82.9	83.4	83.6	83.6	84.4	83.2	84.0	84.5	84.2	84.2

Table B.2c (cont.)

DAT4-5 Mica Compositions

	RIM 3,5	*RIM 3,6*
SiO2	39.26	39.23
TiO2	1.41	1.39
Al2O3	11.77	11.84
Cr2O3	0.07	0.03
FeO	7.35	7.42
MnO	0.11	0.09
MgO	22.45	22.64
CaO	0.06	0.02
Na2O	0.32	0.36
K2O	10.08	10.14
F	0.61	0.90
Cl	0.00	0.00
	93.49	94.06
O=F,Cl	0.26	0.38
Total	93.23	93.68
Cations Based on 23 Oxygens		
Si	6.099	6.081
Ti	0.165	0.162
Al	2.154	2.164
Cr	0.009	0.004
Fe	0.954	0.962
Mn	0.015	0.012
Mg	5.199	5.231
Ca	0.010	0.003
Na	0.098	0.107
K	1.997	2.004
F	0.302	0.440
Cl	0.000	0.000
Total	17.004	17.170
mg	84.5	84.5

mg=Mg/(Mg+total Fe)*100

Table B.2d

OC8-6 Mica Compositions

	CORE 1,1	*CORE 1,2*	*RIM 1,3*	*RIM 1,4*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*CORE 3,2*	*RIM 3,3*	*RIM 3,4*
SiO2	40.88	41.42	41.01	41.27	41.19	41.45	40.56	39.94	39.84	40.15	39.19	39.78
TiO2	1.77	2.08	1.95	1.98	1.93	1.97	1.99	1.89	2.00	1.98	1.97	1.90
Al2O3	13.21	13.12	13.42	13.29	13.14	12.99	13.39	13.32	13.17	13.53	12.96	13.12
Cr2O3	0.05	0.04	0.06	0.05	0.14	0.01	0.12	0.05	0.06	0.06	0.11	0.00
FeO	8.55	9.21	8.68	9.21	8.76	8.57	9.03	8.88	8.65	9.07	9.08	8.62
MnO	0.08	0.08	0.06	0.00	0.11	0.00	0.01	0.02	0.08	0.03	0.04	0.04
MgO	21.23	21.09	20.77	21.30	21.47	21.28	21.44	20.99	21.15	21.30	21.00	21.58
CaO	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00
Na2O	0.35	0.38	0.35	0.42	0.35	0.27	0.32	0.22	0.33	0.44	0.32	0.36
K2O	9.86	9.63	9.92	9.85	9.86	9.78	9.84	9.91	9.76	9.82	9.76	9.57
F	0.78	0.66	0.70	0.44	0.86	1.00	0.64	0.65	0.70	0.78	0.84	0.54
Cl	0.01	0.01	0.04	0.01	0.01	0.02	0.02	0.02	0.02	0.00	0.05	0.01
	96.78	97.72	96.97	97.83	97.82	97.34	97.36	95.89	95.79	97.16	95.33	95.52
O=F,Cl	0.33	0.28	0.30	0.19	0.36	0.43	0.27	0.28	0.30	0.33	0.36	0.23
Total	96.45	97.44	96.67	97.64	97.46	96.91	97.09	95.61	95.49	96.83	94.97	95.29
					Cations Based on 23 Oxygens							
Si	6.132	6.149	6.137	6.114	6.123	6.181	6.056	6.060	6.051	6.022	6.015	6.040
Ti	0.200	0.232	0.220	0.221	0.216	0.221	0.223	0.216	0.228	0.224	0.227	0.217
Al	2.335	2.296	2.366	2.322	2.303	2.284	2.356	2.382	2.358	2.393	2.345	2.348
Cr	0.006	0.005	0.007	0.006	0.016	0.001	0.015	0.005	0.008	0.007	0.013	0.000
Fe	1.073	1.143	1.087	1.141	1.089	1.069	1.128	1.126	1.098	1.138	1.165	1.095
Mn	0.011	0.010	0.008	0.000	0.013	0.000	0.002	0.002	0.010	0.004	0.005	0.005
Mg	4.746	4.667	4.632	4.705	4.757	4.731	4.771	4.747	4.787	4.763	4.805	4.883
Ca	0.002	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.005	0.000	0.002	0.000
Na	0.102	0.109	0.103	0.121	0.100	0.077	0.093	0.066	0.096	0.128	0.096	0.105
K	1.887	1.824	1.894	1.862	1.871	1.860	1.875	1.919	1.891	1.879	1.910	1.853
F	0.369	0.312	0.330	0.208	0.404	0.472	0.302	0.310	0.338	0.369	0.410	0.257
Cl	0.004	0.003	0.009	0.003	0.002	0.005	0.004	0.006	0.004	0.000	0.012	0.004
Total	16.865	16.749	16.794	16.703	16.893	16.900	16.825	16.840	16.874	16.927	17.004	16.809
mg	81.6	80.3	81.0	80.5	81.4	81.6	80.9	80.8	81.3	80.7	80.5	81.7

mg=Mg/(Mg+total Fe)*100

Table B.2d

OC8-6 Mica 2.1, Line Scan Traverse

	29	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*	*40*
SiO2	40.27	39.65	31.90	40.43	39.92	39.62	40.06	40.03	40.32	39.97	40.54	39.96
TiO2	1.93	1.95	1.54	1.91	1.94	1.92	1.92	1.97	1.98	1.90	1.93	1.95
Al2O3	12.91	12.43	8.80	12.52	12.32	12.22	12.58	12.51	12.50	12.43	12.68	12.50
Cr2O3	0.08	0.09	0.05	0.04	0.09	0.06	0.09	0.10	0.07	0.07	0.06	0.09
FeO	8.56	8.92	7.50	8.85	8.65	8.73	8.69	8.80	8.76	8.72	8.60	8.60
MnO	0.06	0.07	0.06	0.06	0.08	0.08	0.09	0.08	0.08	0.08	0.07	0.07
MgO	21.73	21.64	13.92	21.83	21.04	20.81	21.51	21.51	21.51	21.52	21.68	21.66
CaO	0.01	0.03	0.53	0.03	0.13	0.23	0.10	0.05	0.04	0.02	0.02	0.02
Na2O	0.33	0.33	0.16	0.32	0.35	0.30	0.33	0.33	0.36	0.32	0.29	0.33
K2O	10.05	10.03	6.55	10.01	9.75	9.10	9.94	10.14	10.09	10.06	10.07	10.14
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.02	0.02	0.06	0.02	0.04	0.03	0.03	0.02	0.03	0.02	0.03	0.03
	95.97	95.15	71.07	96.02	94.31	93.10	95.33	95.54	95.72	95.11	95.96	95.34
O=F,Cl	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01
Total	95.96	95.15	71.05	96.02	94.30	93.09	95.33	95.53	95.71	95.10	95.95	95.34
Cations Based on 22 Oxygens												
Si	5.801	5.783	6.172	5.828	5.855	5.869	5.816	5.809	5.833	5.822	5.839	5.806
Ti	0.209	0.214	0.224	0.208	0.214	0.214	0.210	0.215	0.216	0.209	0.209	0.213
Al	2.192	2.138	2.007	2.126	2.130	2.134	2.153	2.140	2.131	2.133	2.152	2.140
Cr	0.010	0.010	0.008	0.005	0.010	0.006	0.010	0.012	0.008	0.008	0.007	0.011
Fe	1.032	1.088	1.214	1.066	1.060	1.082	1.055	1.069	1.060	1.062	1.036	1.045
Mn	0.007	0.008	0.009	0.007	0.010	0.010	0.011	0.010	0.009	0.009	0.008	0.009
Mg	4.667	4.705	4.014	4.690	4.599	4.594	4.654	4.653	4.639	4.673	4.654	4.692
Ca	0.002	0.004	0.110	0.005	0.021	0.036	0.016	0.008	0.006	0.004	0.003	0.003
Na	0.093	0.094	0.059	0.089	0.101	0.086	0.093	0.093	0.100	0.090	0.080	0.094
K	1.847	1.866	1.617	1.840	1.824	1.720	1.840	1.878	1.863	1.870	1.851	1.881
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.006	0.004	0.020	0.006	0.009	0.007	0.007	0.005	0.006	0.005	0.007	0.006
Total	15.865	15.914	15.455	15.870	15.833	15.757	15.866	15.891	15.870	15.884	15.845	15.899
mg	81.9	81.2	76.8	81.5	81.3	80.9	81.5	81.3	81.4	81.5	81.8	81.8

Table B.2d (cont.)

OC8-6 Mica 2.1, Line Scan Traverse

	41	*42*	*43*	*44*	*45*	*46*	*47*	*48*	*49*	*50*	*51*	*52*
SiO2	40.82	40.04	39.18	39.91	39.97	39.76	40.34	39.56	40.04	39.84	40.60	39.25
TiO2	1.96	1.88	1.87	1.89	1.94	1.88	1.84	1.89	1.91	1.95	2.03	1.94
Al2O3	12.57	12.61	12.34	12.51	12.75	12.49	12.61	12.44	12.72	12.51	12.61	12.25
Cr2O3	0.10	0.10	0.08	0.09	0.07	0.09	0.09	0.10	0.09	0.11	0.06	0.11
FeO	8.74	8.64	8.68	8.71	8.76	8.72	8.58	8.73	8.73	8.75	8.72	8.83
MnO	0.07	0.05	0.05	0.09	0.09	0.07	0.09	0.07	0.08	0.06	0.05	0.09
MgO	21.61	21.60	21.21	21.21	21.47	21.54	21.37	21.60	21.63	21.57	21.62	20.89
CaO	0.01	0.00	0.05	0.01	0.09	0.09	0.02	0.01	0.01	0.03	0.00	0.07
Na2O	0.29	0.31	0.29	0.31	0.29	0.26	0.30	0.31	0.30	0.30	0.33	0.30
K2O	9.82	10.05	9.97	10.12	9.69	9.73	10.12	9.87	10.12	9.96	9.87	9.65
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.02	0.03	0.01	0.04	0.03	0.03	0.01	0.03	0.02	0.02	0.01	0.01
	96.01	95.31	93.73	94.89	95.15	94.66	95.37	94.59	95.65	95.11	95.90	93.39
O=F,Cl	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00
Total	96.00	95.30	93.73	94.88	95.14	94.65	95.37	94.58	95.65	95.11	95.89	93.39
Cations Based on 22 Oxygens												
Si	5.867	5.814	5.796	5.829	5.806	5.810	5.849	5.793	5.798	5.802	5.846	5.821
Ti	0.212	0.205	0.208	0.208	0.212	0.207	0.201	0.209	0.208	0.214	0.219	0.217
Al	2.129	2.159	2.152	2.154	2.182	2.151	2.156	2.147	2.172	2.147	2.140	2.142
Cr	0.011	0.011	0.010	0.011	0.008	0.010	0.010	0.011	0.010	0.013	0.007	0.013
Fe	1.051	1.049	1.074	1.064	1.064	1.066	1.041	1.069	1.057	1.066	1.050	1.095
Mn	0.009	0.006	0.006	0.011	0.011	0.009	0.011	0.008	0.010	0.007	0.006	0.011
Mg	4.630	4.676	4.678	4.617	4.650	4.693	4.619	4.715	4.669	4.682	4.640	4.619
Ca	0.001	0.000	0.009	0.002	0.015	0.013	0.003	0.002	0.001	0.005	0.000	0.012
Na	0.080	0.087	0.083	0.087	0.082	0.074	0.085	0.087	0.085	0.086	0.091	0.087
K	1.801	1.862	1.883	1.885	1.795	1.813	1.873	1.845	1.870	1.851	1.814	1.825
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.005	0.608	0.002	0.010	0.008	0.008	0.003	0.007	0.005	0.004	0.003	0.003
Total	15.797	15.878	15.899	15.877	15.833	15.854	15.850	15.892	15.885	15.876	15.817	15.844
mg	81.5	81.7	81.3	81.3	81.4	81.5	81.6	81.5	81.5	81.5	81.5	80.8

mg=Mg/(Mg+total Fe)*100

Table B.2d (cont.)

OC8-6 Mica 2.1, Line Scan Traverse

	53	54	55	56	57	58	59	60	61	62	63	64
SiO2	41.40	39.77	39.81	39.70	39.87	39.85	39.63	33.06	39.17	39.32	39.98	39.57
TiO2	1.98	1.94	1.97	2.01	1.98	1.91	1.92	1.66	2.02	1.98	2.00	1.94
Al2O3	13.09	12.47	12.60	12.52	12.41	12.33	12.56	9.64	12.39	12.38	12.56	12.41
Cr2O3	0.08	0.06	0.09	0.06	0.09	0.11	0.05	0.07	0.07	0.07	0.10	0.11
FeO	8.75	8.70	8.62	8.58	8.61	8.59	8.69	7.65	8.90	8.88	8.88	8.81
MnO	0.04	0.07	0.05	0.04	0.06	0.06	0.05	0.05	0.04	0.05	0.04	0.04
MgO	22.40	21.25	21.33	21.46	21.38	21.23	21.27	15.84	20.97	20.98	21.60	21.62
CaO	0.05	0.03	0.00	0.00	0.02	0.03	0.00	0.16	0.08	0.04	0.00	0.00
Na2O	0.32	0.30	0.34	0.34	0.33	0.31	0.37	0.21	0.28	0.33	0.33	0.34
K2O	9.80	9.86	9.79	10.11	9.97	9.82	9.99	8.40	9.82	10.05	9.99	9.93
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.02	0.02	0.01	0.01	0.02	0.02	0.03	0.02	0.03	0.04	0.02	0.02
	97.94	94.45	94.60	94.83	94.73	94.25	94.55	76.74	93.75	94.11	95.49	94.80
O=F,Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.01
Total	97.93	94.45	94.60	94.83	94.72	94.24	94.54	76.74	93.75	94.10	95.48	94.80
Cations Based on 22 Oxygens												
Si	5.824	5.825	5.817	5.799	5.825	5.846	5.807	5.986	5.794	5.802	5.800	5.787
Ti	0.210	0.213	0.217	0.221	0.217	0.210	0.212	0.225	0.225	0.220	0.219	0.214
Al	2.171	2.153	2.169	2.156	2.137	2.132	2.169	2.058	2.161	2.153	2.147	2.140
Cr	0.009	0.007	0.010	0.007	0.011	0.013	0.005	0.009	0.008	0.008	0.011	0.013
Fe	1.030	1.066	1.053	1.048	1.052	1.053	1.064	1.158	1.101	1.096	1.077	1.077
Mn	0.004	0.009	0.007	0.005	0.007	0.007	0.007	0.007	0.005	0.006	0.005	0.005
Mg	4.698	4.640	4.645	4.672	4.656	4.643	4.645	4.274	4.624	4.615	4.672	4.713
Ca	0.008	0.004	0.000	0.000	0.003	0.005	0.000	0.031	0.012	0.007	0.000	0.000
Na	0.088	0.086	0.096	0.096	0.092	0.089	0.105	0.075	0.080	0.094	0.092	0.096
K	1.760	1.842	1.825	1.883	1.858	1.838	1.867	1.940	1.853	1.892	1.850	1.853
F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cl	0.004	0.005	0.003	0.003	0.004	0.004	0.007	0.006	0.007	0.011	0.005	0.006
Total	15.804	15.850	15.840	15.891	15.863	15.839	15.887	15.768	15.870	15.902	15.879	15.904
mg	82.0	81.3	81.5	81.7	81.6	81.5	81.4	78.7	80.8	80.8	81.3	81.4

Table B.2d (cont.)

OC8-6 Mica 2.1, Line Scan Traverse

	65	66	67
SiO2	39.65	39.45	39.72
TiO2	1.96	1.96	1.99
Al2O3	12.46	12.34	12.56
Cr2O3	0.08	0.04	0.06
FeO	8.65	8.59	8.57
MnO	0.06	0.04	0.05
MgO	21.29	21.29	21.58
CaO	0.04	0.01	0.00
Na2O	0.34	0.35	0.33
K2O	9.96	10.07	10.02
F	0.00	0.00	0.00
Cl	0.02	0.03	0.01
	94.51	94.16	94.89
O=F,Cl	0.00	0.01	0.00
Total	94.50	94.16	94.88
Cations Based on 22 Oxygens			
Si	5.811	5.808	5.795
Ti	0.216	0.217	0.218
Al	2.153	2.141	2.160
Cr	0.010	0.005	0.007
Fe	1.060	1.057	1.046
Mn	0.007	0.005	0.006
Mg	4.651	4.672	4.693
Ca	0.006	0.001	0.000
Na	0.097	0.101	0.094
K	1.862	1.892	1.866
F	0.000	0.000	0.000
Cl	0.004	0.007	0.003
Total	15.876	15.905	15.886
mg	81.4	81.5	81.8

mg=Mg/(Mg+total Fe)*100

Table B.2e

OC8-9 Mica Compositions

	RIM 1,3	*CORE 1,4*	*CORE 1,5*	*RIM 1,6*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*RIM 3,2*	*RIM 3,3*	*CORE 3,4*
SiO2	39.60	39.98	40.16	40.00	39.70	39.76	39.51	39.58	39.12	39.16	39.20	39.96
TiO2	1.98	1.82	1.82	1.81	1.90	1.82	1.77	1.88	1.93	1.78	1.87	1.80
Al2O3	13.62	13.14	13.33	13.06	13.21	13.28	13.34	13.18	13.29	13.10	13.30	13.01
Cr2O3	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.09	0.02	0.00	0.00	0.00
FeO	10.18	9.69	9.63	8.57	9.20	9.09	9.42	9.06	9.39	9.71	10.02	9.18
MnO	0.05	0.06	0.10	0.05	0.01	0.02	0.01	0.01	0.07	0.09	0.13	0.06
MgO	21.82	21.81	22.31	22.08	21.87	21.79	21.89	21.94	21.94	21.89	21.71	21.69
CaO	0.10	0.05	0.06	0.19	0.01	0.04	0.06	0.10	0.00	0.00	0.01	0.01
Na2O	0.42	0.35	0.40	0.43	0.43	0.34	0.41	0.40	0.43	0.37	0.41	0.41
K2O	9.38	9.59	9.54	9.94	10.18	9.74	9.81	10.05	10.21	9.97	10.10	10.14
F	0.65	0.84	0.75	1.07	0.91	0.60	1.03	0.66	0.84	0.47	0.78	0.72
Cl	0.02	0.03	0.03	0.03	0.00	0.02	0.03	0.02	0.03	0.02	0.04	0.02
	97.82	97.37	98.13	97.23	97.42	96.50	97.28	96.97	97.27	96.56	97.57	97.00
O=F,Cl	0.28	0.36	0.32	0.46	0.38	0.26	0.44	0.28	0.36	0.20	0.34	0.31
Total	97.54	97.01	97.81	96.77	97.04	96.24	96.84	96.69	96.91	96.36	97.23	96.69
Cations Based on 22 Oxygens												
Si	5.663	5.744	5.717	5.756	5.715	5.738	5.700	5.706	5.655	5.679	5.659	5.762
Ti	0.213	0.197	0.195	0.196	0.206	0.198	0.192	0.204	0.210	0.194	0.203	0.195
Al	2.295	2.225	2.237	2.215	2.241	2.259	2.268	2.240	2.265	2.239	2.262	2.211
Cr	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.011	0.002	0.000	0.000	0.000
Fe	1.218	1.164	1.147	1.031	1.108	1.097	1.137	1.092	1.135	1.178	1.209	1.107
Mn	0.006	0.008	0.012	0.006	0.001	0.003	0.002	0.002	0.009	0.011	0.016	0.007
Mg	4.652	4.670	4.733	4.735	4.693	4.687	4.707	4.715	4.726	4.732	4.670	4.662
Ca	0.016	0.008	0.009	0.030	0.001	0.006	0.009	0.016	0.000	0.000	0.002	0.002
Na	0.117	0.099	0.109	0.120	0.120	0.096	0.115	0.112	0.121	0.105	0.116	0.116
K	1.711	1.758	1.733	1.824	1.869	1.794	1.805	1.848	1.883	1.845	1.859	1.865
F	0.294	0.382	0.336	0.486	0.413	0.274	0.470	0.301	0.386	0.216	0.355	0.329
Cl	0.004	0.007	0.007	0.007	0.000	0.006	0.006	0.006	0.007	0.006	0.009	0.004
Total	16.189	16.263	16.233	16.405	16.367	16.159	16.410	16.252	16.398	16.204	16.359	16.261
mg	79.3	80.0	80.5	82.1	80.9	81.0	80.5	81.2	80.6	80.1	79.4	80.8

Table B.2e (cont.)

OC8-9 Mica Compositions

	CORE 1,1	*CORE 1,2*
SiO2	33.46	37.22
TiO2	1.74	1.79
Al2O3	12.07	11.93
Cr2O3	0.00	0.01
FeO	9.57	9.24
MnO	0.05	0.00
MgO	21.95	21.43
CaO	0.03	0.00
Na2O	0.38	0.39
K2O	9.83	9.86
F	0.91	0.93
Cl	0.04	0.02
	90.03	92.82
O=F,Cl	0.39	0.40
Total	89.64	92.42
Cations Based on 22 Oxygens		
Si	5.323	5.665
Ti	0.208	0.204
Al	2.262	2.140
Cr	0.000	0.002
Fe	1.273	1.175
Mn	0.007	0.000
Mg	5.205	4.860
Ca	0.005	0.000
Na	0.117	0.115
K	1.995	1.914
F	0.460	0.447
Cl	0.010	0.005
Total	16.863	16.526
mg	80.4	80.5

mg=Mg/(Mg+total Fe)*100

Table B.2f

OC8-12 Mica Compositions

	CORE 1,1	*CORE 1,2*	*MID 1,3*	*MID 1,4*	*RIM 1,5*	*RIM 1,6*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*CORE 3,2*
SiO2	38.45	38.18	38.35	38.41	37.45	38.42	38.31	38.56	38.30	38.01	38.43	37.87
TiO2	1.31	1.78	1.58	1.47	1.68	1.61	1.34	1.29	1.59	1.58	1.49	1.60
Al2O3	13.04	13.61	13.47	12.93	13.78	13.75	13.37	12.72	13.41	13.39	13.03	13.00
Cr2O3	0.20	0.23	0.22	0.28	0.20	0.09	0.17	0.11	0.40	0.30	0.34	0.25
FeO	8.39	9.02	8.89	9.30	9.25	8.58	8.94	9.14	8.94	8.83	8.88	9.00
MnO	0.01	0.05	0.07	0.15	0.13	0.10	0.06	0.05	0.05	0.07	0.09	0.05
MgO	21.55	20.39	20.58	21.02	20.47	20.80	21.00	20.44	20.68	20.19	20.54	21.23
CaO	0.00	0.02	0.03	0.02	0.04	0.14	0.03	0.00	0.08	0.06	0.02	0.01
Na2O	0.37	0.45	0.46	0.45	0.41	0.51	0.39	0.43	0.38	0.44	0.50	0.49
K2O	10.00	9.73	9.83	9.71	9.60	9.67	9.80	9.74	9.51	9.63	9.78	9.79
F	0.67	0.57	0.53	0.46	0.32	0.39	0.21	0.78	0.50	0.53	0.46	0.18
Cl	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00
	93.99	94.04	94.01	94.20	93.33	94.07	93.62	93.26	93.84	93.04	93.56	93.47
O=F,Cl	0.28	0.24	0.22	0.19	0.13	0.17	0.09	0.33	0.21	0.23	0.19	0.08
Total	93.71	93.80	93.79	94.01	93.20	93.90	93.53	92.93	93.63	92.81	93.37	93.39
					Cations Based on 23 Oxygens							
Si	5.973	5.933	5.957	5.966	5.861	5.941	5.955	6.055	5.951	5.964	5.997	5.911
Ti	0.154	0.208	0.185	0.171	0.198	0.187	0.157	0.152	0.186	0.186	0.175	0.188
Al	2.388	2.492	2.466	2.366	2.542	2.505	2.449	2.355	2.456	2.476	2.396	2.392
Cr	0.024	0.028	0.028	0.034	0.025	0.011	0.021	0.014	0.050	0.037	0.042	0.031
Fe	1.090	1.172	1.155	1.207	1.211	1.110	1.162	1.201	1.162	1.159	1.159	1.175
Mn	0.002	0.006	0.009	0.020	0.017	0.013	0.008	0.007	0.006	0.009	0.013	0.006
Mg	4.991	4.724	4.764	4.865	4.776	4.794	4.866	4.784	4.790	4.721	4.776	4.939
Ca	0.000	0.003	0.006	0.004	0.007	0.024	0.006	0.000	0.014	0.010	0.003	0.001
Na	0.111	0.136	0.138	0.136	0.126	0.154	0.117	0.131	0.113	0.135	0.151	0.148
K	1.982	1.929	1.948	1.924	1.918	1.908	1.944	1.950	1.885	1.927	1.947	1.948
F	0.329	0.278	0.261	0.225	0.158	0.190	0.105	0.386	0.244	0.265	0.228	0.088
Cl	0.000	0.002	0.001	0.000	0.000	0.004	0.000	0.000	0.000	0.002	0.001	0.000
Total	17.043	16.911	16.916	16.918	16.837	16.839	16.789	17.035	16.854	16.891	16.886	16.827
mg	82.1	80.1	80.5	80.1	79.8	81.2	80.7	79.9	80.5	80.3	80.5	80.8

Table B.2f (cont.)

OC8-12 Mica Compositions

	RIM 3,3	*RIM 3,4*
SiO2	38.08	38.56
TiO2	1.57	1.55
Al2O3	13.29	13.06
Cr2O3	0.15	0.24
FeO	9.09	8.46
MnO	0.09	0.06
MgO	20.68	20.65
CaO	0.11	0.16
Na2O	0.34	0.40
K2O	9.54	9.81
F	0.39	0.54
Cl	0.01	0.00
	93.34	93.49
O=F,Cl	0.17	0.23
Total	93.17	93.26
	Cations Based on 23 Oxygens	
Si	5.948	6.011
Ti	0.184	0.181
Al	2.447	2.400
Cr	0.018	0.030
Fe	1.880	1.104
Mn	0.013	0.008
Mg	4.816	4.797
Ca	0.019	0.027
Na	0.104	0.120
K	1.900	1.950
F	0.194	0.264
Cl	0.003	0.000
Total	17.526	16.892
mg	71.9	81.3

mg=Mg/(Mg+total Fe)*100

Table B.2g

OC8-17 Mica Compositions

	CORE 3,1	***CORE 3,2***	***CORE 3,3***	***CORE 3,4***	***CORE 3,5***	***CORE 3,6***	***RIM 3,7***	***RIM 3,8***	***RIM 3,9***	***RIM 3,10***	***RIM 3,11***	***RIM 3,12***
SiO2	37.27	38.14	37.33	37.78	37.87	37.92	37.60	38.63	36.88	37.51	37.97	38.16
TiO2	2.07	1.99	1.82	2.07	2.14	1.88	2.19	1.79	2.42	2.24	2.23	2.23
Al2O3	14.07	14.42	14.09	13.89	13.99	14.08	14.65	14.30	15.42	15.03	14.33	14.17
Cr2O3	0.08	0.03	0.01	0.00	0.07	0.00	0.00	0.10	0.00	0.06	0.06	0.00
FeO	10.89	11.26	11.19	10.86	11.13	11.26	8.39	7.20	11.70	10.48	7.90	7.49
MnO	0.06	0.04	0.10	0.10	0.07	0.07	0.04	0.04	0.11	0.06	0.08	0.07
MgO	18.88	18.63	18.75	18.62	18.29	18.92	19.96	21.32	17.54	18.41	21.08	21.07
CaO	0.00	0.02	0.01	0.01	0.00	0.02	0.02	0.02	0.04	0.08	0.08	0.06
Na2O	0.39	0.47	0.36	0.40	0.51	0.49	0.57	0.50	0.53	0.46	0.44	0.42
K2O	10.18	10.02	10.04	10.21	10.10	10.07	10.11	10.29	9.85	9.79	10.29	10.27
F	0.30	0.37	0.51	0,44	0.45	0.50	0.66	0.54	0.47	0.72	0.63	0.69
Cl	0.02	0.02	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.01
	94.21	95.41	94.21	94.38	94.62	95.22	94.20	94.74	94.98	94.85	95.10	94.64
O=F,Cl	0.13	0.16	0.21	0.19	0.19	0.21	0.28	0.23	0.20	0.31	0.27	0.29
Total	94.08	95.25	94.00	94.19	94.43	95.01	93.92	94.51	94.78	94.54	94.83	94.35
Cations Based on 23 Oxygens												
Si	5.840	5.892	5.861	5.909	5.912	5.887	5.835	5.914	5.750	5.827	5.827	5.871
Ti	0.245	0.231	0.215	0.243	0.252	0.219	0.255	0.207	0.284	0.262	0.258	0.258
Al	2.599	2.625	2.607	2.561	2.574	2.577	2.680	2.579	2.833	2.752	2.592	2.570
Cr	0.009	0.004	0.001	0.000	0.009	0.000	0.000	0.012	0.000	0.007	0.008	0.000
Fe	1.428	1.455	1.470	1.421	1.453	1.462	1.089	0.922	1.526	1.362	1.013	0.964
Mn	0.008	0.005	0.013	0.013	0.010	0.009	0.006	0.005	0.015	0.008	0.011	0.009
Mg	4.409	4.290	4.390	4.341	4.256	4.377	4.615	4.864	4.076	4.263	4.822	4.833
Ca	0.000	0.003	0.002	0.002	0.000	0.003	0.003	0.004	0.007	0.013	0.014	0.010
Na	0.118	0.141	0.108	0.120	0.154	0.147	0.171	0.148	0.159	0.139	0.130	0.126
K	2.035	1.974	2.011	2.037	2.010	1.994	2.002	2.008	1.959	1.940	2.015	2.016
F	0.148	0.179	0.255	0.218	0.224	0.245	0.323	0.261	0.232	0.355	0.304	0.336
Cl	0.005	0.006	0.000	0.001	0.001	0.003	0.002	0.002	0.006	0.003	0.002	0.004
Total	16.841	16.805	16.934	16.866	16.852	16.923	16.981	16.925	16.846	16.930	16.994	16.997
mg	75.5	74.7	74.9	75.3	74.5	75.0	80.9	84.1	72.8	75.8	82.6	83.4

Table B.2g (cont.)

OC8-17 Mica Compositions

	CORE 2,1	***CORE 2,2***	***CORE 2,3***	***CORE 2,4***	***RIM 2,5***	***RIM 2,6***	***RIM 2,7***	***RIM 2,8***	***CORE 1,1***	***CORE 1,2***	***CORE 1,3***	***RIM 1,4***
SiO2	37.03	38.02	37.63	37.59	37.16	37.66	38.91	37.60	36.98	36.62	37.65	37.95
TiO2	2.13	2.14	2.31	2.09	2.35	2.24	1.83	2.22	2.12	2.27	2.01	1.83
Al2O3	14.74	14.20	15.37	14.91	15.37	15.41	14.26	15.61	15.63	15.56	14.79	14.87
Cr2O3	0.00	0.07	0.02	0.09	0.04	0.05	0.13	0.03	0.06	0.00	0.05	0.15
FeO	11.74	11.21	11.48	11.65	9.04	9.65	6.58	9.33	11.37	11.98	11.62	8.57
MnO	0.12	0.05	0.12	0.11	0.04	0.09	0.04	0.09	0.05	0.05	0.07	0.10
MgO	18.14	18.44	17.89	17.79	19.34	18.86	21.96	19.35	17.65	17.35	18.09	19.84
CaO	0.01	0.01	0.03	0.00	0.03	0.03	0.04	0.02	0.03	0.00	0.01	0.05
Na2O	0.58	0.57	0.50	0.54	0.51	0.47	0.46	0.53	0.45	0.46	0.60	0.49
K2O	9.93	10.02	9.96	9.97	9.84	10.00	10.21	10.03	9.92	9.77	9.75	9.90
F	0.28	0.56	0.31	0.48	0.39	0.30	0.67	0.65	0.58	0.42	0.44	0.57
Cl	0.01	0.00	0.02	0.01	0.01	0.03	0.01	0.01	0.02	0.02	0.02	0.02
	94.71	95.29	95.64	95.23	94.12	94.79	95.10	95.47	94.86	94.50	95.10	94.34
O=F,Cl	0.12	0.24	0.14	0.20	0.17	0.13	0.28	0.28	0.25	0.18	0.19	0.24
Total	94.59	95.05	95.50	95.03	93.95	94.66	94.82	95.19	94.61	94.32	94.91	94.10
Cations Based on 23 Oxygens												
Si	5.787	5.897	5.802	5.841	5.764	5.810	5.919	5.772	5.766	5.739	5.848	5.866
Ti	0.251	0.249	0.268	0.244	0.274	0.260	0.210	0.257	0.249	0.268	0.235	0.213
Al	2.714	2.595	2.793	2.731	2.810	2.801	2.556	2.823	2.872	2.874	2.708	2.709
Cr	0.000	0.009	0.003	0.011	0.005	0.006	0.016	0.004	0.007	0.000	0.006	0.018
Fe	1.534	1.455	1.480	1.514	1.173	1.245	0.838	1.198	1.483	1.570	1.509	1.108
Mn	0.016	0.006	0.015	0.015	0.006	0.012	0.005	0.011	0.006	0.006	0.009	0.014
Mg	4.225	4.264	4.111	4.121	4.471	4.335	4.979	4.428	4.103	4.053	4.188	4.571
Ca	0.002	0.002	0.005	0.000	0.005	0.005	0.007	0.003	0.004	0.000	0.002	0.009
Na	0.175	0.170	0.150	0.162	0.153	0.139	0.135	0.159	0.137	0.141	0.180	0.148
K	1.979	1.983	1.960	1.977	1.947	1.967	1.981	1.964	1.973	1.953	1.932	1.953
F	0.138	0.273	0.150	0.237	0.190	0.145	0.323	0.315	0.285	0.206	0.218	0.280
Cl	0.002	0.000	0.004	0.002	0.002	0.007	0.002	0.003	0.004	0.005	0.005	0.006
Total	16.823	16.901	16.741	16.853	16.798	16.732	16.969	16.936	16.891	16.814	16.839	16.893
mg	73.4	74.6	73.5	73.1	79.2	77.7	85.6	78.7	73.4	72.1	73.5	80.5

mg=Mg/(Mg+total Fe)*100

Table B.h

AU26-5 Mica Compositions

	CORE 1,1	*CORE 1,2*	*CORE 1,3*	*CORE 1,4*	*RIM 1,5*	*RIM 1,6*	*RIM 1,7*	*RIM 1,8*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*
SiO2	39.76	39.61	39.53	40.09	38.26	37.78	37.07	38.15	38.50	39.49	38.76	39.51
TiO2	1.81	1.99	1.82	1.84	2.97	2.10	2.96	1.84	2.11	1.94	2.43	2.37
Al2O3	12.80	12.94	12.57	12.78	13.96	13.40	14.06	12.69	13.29	13.02	13.64	13.46
Cr2O3	0.00	0.07	0.16	0.13	0.01	0.00	0.00	0.07	0.00	0.00	0.03	0.06
FeO	8.48	9.06	8.62	9.03	11.91	11.73	10.38	13.02	11.98	12.35	11.36	9.21
MnO	0.06	0.06	0.05	0.07	0.16	0.13	0.03	0.19	0.06	0.10	0.06	0.17
MgO	22.51	22.04	22.57	22.51	18.89	20.47	20.23	20.15	20.80	20.43	19.95	21.32
CaO	0.03	0.00	0.02	0.03	0.03	0.02	0.08	0.03	0.00	0.01	0.04	0.05
Na2O	0.30	0.36	0.41	0.41	0.42	0.47	0.41	0.36	0.34	0.44	0.42	0.47
K2O	10.27	10.32	10.22	10.12	9.74	9.97	9.92	9.94	10.02	10.13	9.81	9.88
F	0.89	0.94	0.76	0.94	1.09	0.56	1.22	0.59	0.89	0.82	0.90	0.69
Cl	0.01	0.03	0.02	0.00	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.02
	96.92	97.42	96.75	97.95	97.46	96.66	96.39	97.04	98.00	98.74	97.41	97.21
O=F,Cl	0.38	0.40	0.32	0.40	0.46	0.24	0.52	0.25	0.38	0.35	0.38	0.30
Total	96.54	97.02	96.43	97.55	97.00	96.42	95.87	96.79	97.62	98.39	97.03	96.91
					Cations Based on 22 Oxygens							
Si	5.739	5.711	5.721	5.736	5.590	5.552	5.469	5.618	5.592	5.690	5.636	5.685
Ti	0.196	0.216	0.198	0.198	0.326	0.233	0.328	0.204	0.230	0.210	0.265	0.257
Al	2.178	2.198	2.144	2.156	2.404	2.322	2.446	2.202	2.276	2.211	2.338	2.283
Cr	0.000	0.009	0.018	0.015	0.001	0.000	0.000	0.008	0.000	0.000	0.004	0.006
Fe	1.023	1.093	1.043	1.080	1.455	1.442	1.280	1.604	1.455	1.488	1.382	1.108
Mn	0.008	0.008	0.007	0.009	0.020	0.017	0.004	0.024	0.007	0.012	0.007	0.020
Mg	4.842	4.736	4.868	4.800	4.113	4.485	4.448	4.424	4.503	4.389	4.323	4.573
Ca	0.005	0.000	0.003	0.005	0.004	0.003	0.013	0.004	0.000	0.001	0.006	0.008
Na	0.085	0.100	0.115	0.115	0.120	0.133	0.117	0.102	0.095	0.123	0.117	0.132
K	1.890	1.898	1.888	1.848	1.815	1.869	1.866	1.868	1.857	1.862	1.819	1.814
F	0.406	0.430	0.347	0.424	0.502	0.261	0.571	0.273	0.409	0.375	0.414	0.315
Cl	0.002	0.006	0.004	0.000	0.006	0.006	0.007	0.003	0.003	0.004	0.003	0.005
Total	16.372	16.404	16.354	16.385	16.356	16.322	16.549	16.334	16.427	16.366	16.313	16.206
mg	82.6	81.3	82.4	81.6	73.9	75.7	77.6	73.4	75.6	74.7	75.8	80.5

Table B.h (cont.)

AU26-5 Mica Compositions

	CORE 2,5	*CORE 3,1*	*CORE 3,2*	*RIM 3,3*		*RIM 3,4*
SiO2	38.30	39.33	38.73	39.31	37.74	
TiO2	1.74	1.23	1.06	2.30	2.55	
Al2O3	13.20	12.69	12.79	13.30	13.86	
Cr2O3	0.08	1.15	0.98	0.12	0.04	
FeO	9.84	8.89	7.56	10.51	12.47	
MnO	0.09	0.00	0.01	0.04	0.10	
MgO	22.07	22.91	23.95	20.94	18.93	
CaO	0.00	0.01	0.03	0.03	0.05	
Na2O	0.45	0.40	0.29	0.46	0.45	
K2O	10.09	10.47	10.46	10.07	9.92	
F	0.87	0.63	1.17	1.44	0.78	
Cl	0.00	0.02	0.00	0.02	0.01	
	96.73	97.73	97.03	98.54	96.90	
O=F,Cl	0.37	0.27	0.49	0.61	0.33	
Total	96.36	97.46	96.54	97.93	96.57	
					Cations Based on 22 Oxygens	
Si	5.59	5.66	5.61	5.66	5.56	
Ti	0.19	0.13	0.12	0.25	0.28	
Al	2.27	2.15	2.18	2.26	2.41	
Cr	0.01	0.13	0.11	0.01	0.01	
Fe	1.20	1.07	0.92	1.27	1.53	
Mn	0.01	0.00	0.00	0.01	0.01	
Mg	4.80	4.91	5.17	4.50	4.15	
Ca	0.00	0.00	0.00	0.00	0.01	
Na	0.13	0.11	0.08	0.13	0.13	
K	1.88	1.92	1.93	1.85	1.86	
F	0.40	0.29	0.53	0.66	0.36	
Cl	0.00	0.01	0.00	0.01	0.00	
Total	16.49	16.38	16.67	16.60	16.31	
mg	80.0	82.1	85.0	78.0	73.0	

mg=Mg/(Mg+total Fe)*100

Table B.2i

AU26-10 Mica Compositions

	CORE 2,1	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 4,1*	*CORE 4,2*	*CORE 4,3*	*RIM 4,4*	*RIM 4,5*	*RIM 4,6*	*CORE 4,7*	*CORE 6,1*
SiO2	38.57	39.21	37.08	37.73	38.50	38.62	29.37	37.41	37.33	36.91	34.45	38.81
TiO2	1.73	1.56	2.87	2.06	1.73	1.75	1.70	2.86	2.47	2.54	1.74	2.10
Al2O3	13.59	13.75	13.23	14.52	13.87	13.88	13.42	14.07	15.27	15.45	13.76	14.10
Cr2O3	0.04	0.04	0.02	0.00	0.00	0.06	0.00	0.00	0.00	0.03	0.05	0.00
FeO	8.27	7.48	12.09	11.59	8.32	8.89	9.22	9.12	10.38	11.26	8.53	10.02
MnO	0.03	0.07	0.11	0.15	0.01	0.10	0.04	0.06	0.10	0.13	0.05	0.09
MgO	20.89	21.56	18.76	17.94	20.58	20.83	19.54	20.15	18.69	18.00	21.27	19.58
CaO	0.00	0.01	0.00	0.04	0.01	0.00	0.01	0.07	0.03	0.07	0.01	0.03
Na2O	0.26	0.26	0.40	0.58	0.40	0.36	0.37	0.43	0.52	0.51	0.29	0.29
K2O	10.43	10.49	9.93	9.85	10.37	10.31	10.11	9.92	9.84	9.99	10.55	10.42
F	0.54	0.68	0.52	0.50	0.68	0.79	0.89	0.77	0.45	0.59	0.91	0.44
Cl	0.00	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.02	0.01	0.02	0.01
	94.35	95.12	95.02	94.98	94.49	95.60	84.67	94.86	95.10	95.49	91.63	95.89
O=F,Cl	0.23	0.29	0.22	0.22	0.29	0.33	0.37	0.32	0.19	0.25	0.39	0.19
Total	94.12	94.83	94.80	94.76	94.20	95.27	84.30	94.54	94.91	95.24	91.24	95.70
						Cations Based on 23 Oxygens						
Si	5.962	5.991	5.810	5.877	5.951	5.922	5.248	5.793	5.769	5.725	5.589	5.939
Ti	0.201	0.179	0.338	0.241	0.201	0.202	0.229	0.333	0.287	0.296	0.212	0.241
Al	2.476	2.477	2.444	2.665	2.527	2.509	2.827	2.569	2.782	2.824	2.631	2.543
Cr	0.005	0.005	0.003	0.000	0.000	0.007	0.000	0.000	0.000	0.003	0.006	0.000
Fe	1.069	0.956	1.585	1.509	1.075	1.141	1.377	1.182	1.342	1.461	1.157	1.282
Mn	0.004	0.009	0.014	0.020	0.002	0.013	0.006	0.008	0.013	0.017	0.006	0.011
Mg	4.813	4.910	4.381	4.165	4.743	4.762	5.206	4.650	4.306	4.162	5.142	4.467
Ca	0.000	0.002	0.001	0.007	0.002	0.000	0.002	0.011	0.005	0.011	0.001	0.005
Na	0.079	0.076	0.123	0.175	0.119	0.107	0.128	0.130	0.156	0.154	0.092	0.085
K	2.057	2.045	1.985	1.957	2.044	2.017	2.306	1.960	1.941	1.978	2.182	2.033
F	0.265	0.327	0.257	0.247	0.330	0.382	0.502	0.378	0.218	0.290	0.469	0.215
Cl	0.001	0.003	0.003	0.005	0.004	0.004	0.000	0.000	0.005	0.002	0.007	0.003
Total	16.931	16.980	16.943	16.868	17.000	17.065	17.829	17.013	16.823	16.923	17.494	16.825
mg	81.8	83.7	73.4	73.4	81.5	80.7	79.1	79.7	76.2	74.0	81.6	77.7

Table B.2i (cont.)

AU26-10 Mica Compositions

	CORE 6,2	*CORE 6,3*	*RIM 6,4*	*CORE X,1*	*RIM X,2*
SiO2	37.53	37.22	36.36	38.98	38.45
TiO2	1.98	2.78	2.80	1.57	2.03
Al2O3	13.92	14.10	13.66	13.72	14.46
Cr2O3	0.00	0.06	0.00	0.07	0.00
FeO	9.92	8.99	10.57	8.40	6.53
MnO	0.05	0.04	0.13	0.10	0.07
MgO	19.90	20.05	19.15	20.94	21.63
CaO	0.05	0.02	0.09	0.00	0.12
Na2O	0.29	0.41	0.44	0.37	0.46
K2O	10.18	9.98	10.19	10.54	10.17
F	0.47	0.80	0.60	0.60	1.06
Cl	0.00	0.01	0.00	0.01	0.01
	94.29	94.46	93.99	95.30	94.99
O=F,Cl	0.20	0.34	0.25	0.25	0.45
Total	94.09	94.12	93.74	95.05	94.54
					Cations Based on 23 Oxygens
Si	5.853	5.790	5.744	5.974	5.883
Ti	0.232	0.326	0.333	0.181	0.234
Al	2.560	2.586	2.543	2.479	2.607
Cr	0.000	0.007	0.000	0.008	0.000
Fe	1.293	1.170	1.396	1.077	0.836
Mn	0.007	0.005	0.017	0.013	0.010
Mg	4.626	4.649	4.508	4.784	4.932
Ca	0.008	0.003	0.015	0.000	0.019
Na	0.089	0.123	0.134	0.111	0.136
K	2.026	1.981	2.054	2.061	1.985
F	0.230	0.392	0.300	0.290	0.512
Cl	0.000	0.002	0.000	0.003	0.002
Total	16.923	17.034	17.046	16.981	17.154
mg	78.2	79.9	76.4	81.6	85.5

mg=Mg/(Mg+total Fe)*100

Table B.3a

OC7-1 Apatite Groundmass Compositions

	GM 1	*GM 2*	*GM 3*	*GM 4*	*GM 5*	*GM 6*	*GM 7*	*GM 8*	*GM 9*	*GM 10*	*GM 11*	*GM 12*
SiO2	12.13	19.17	7.23	11.27	24.13	0.79	0.27	0.38	5.07	0.42	0.77	1.78
FeO	1.65	0.63	1.98	1.17	0.50	0.62	0.54	0.64	0.90	0.60	0.75	0.86
MnO	0.06	0.02	0.02	0.02	0.00	0.03	0.02	0.03	0.05	0.03	0.06	0.04
MgO	4.32	0.67	4.19	2.84	0.36	0.58	0.64	0.59	1.26	0.66	1.17	1.36
CaO	39.93	30.96	45.30	41.81	24.97	52.48	53.40	53.24	47.63	52.91	51.10	51.36
P2O5	29.84	23.99	35.02	31.73	18.44	39.88	40.29	39.23	35.75	39.14	39.61	37.88
Na2O	0.29	0.63	0.22	0.91	4.61	0.20	0.01	0.03	0.16	0.04	0.03	0.07
SO3	0.28	0.18	0.26	0.42	0.19	0.36	0.35	0.23	0.33	0.38	0.47	0.41
F	1.91	1.15	1.79	2.31	1.05	2.52	1.77	2.75	1.99	2.21	1.95	3.33
Cl	0.15	0.06	0.15	0.10	0.03	0.21	0.13	0.21	0.15	0.16	0.16	0.17
Total	89.72	76.96	95.37	91.56	73.83	96.54	96.65	96.13	92.41	95.59	95.21	95.83
O=F,Cl	0.84	0.50	0.79	1.00	0.45	1.11	0.77	1.21	0.87	0.97	0.86	1.44
						Cations Based on 25 Oxygens						
Si	2.183	3.838	1.239	1.990	5.031	0.137	0.046	0.067	0.902	0.074	0.134	0.313
Fe	0.248	0.106	0.284	0.173	0.088	0.089	0.078	0.094	0.133	0.087	0.109	0.126
Mn	0.009	0.003	0.004	0.002	0.000	0.004	0.003	0.004	0.007	0.004	0.009	0.006
Mg	1.158	0.199	1.071	0.749	0.113	0.148	0.165	0.155	0.335	0.173	0.303	0.356
Ca	7.695	6.643	8.320	7.913	5.578	9.720	9.848	9.984	9.088	9.926	9.530	9.651
P	4.544	4.067	5.083	4.745	3.256	5.837	5.871	5.813	5.390	5.802	5.837	5.625
Na	0.099	0.244	0.074	0.311	1.863	0.066	0.004	0.011	0.054	0.015	0.010	0.024
S	0.038	0.028	0.034	0.056	0.029	0.046	0.045	0.030	0.044	0.049	0.061	0.054
F	1.085	0.729	0.969	1.292	0.694	1.378	0.963	1.524	1.121	1.226	1.072	1.845
Cl	0.045	0.019	0.045	0.030	0.009	0.063	0.038	0.061	0.046	0.048	0.048	0.051
Total	17.105	15.877	17.121	17.258	16.661	17.489	17.061	17.743	17.119	17.405	17.112	18.050
X(F)	0.543	0.364	0.485	0.646	0.347	0.689	0.482	0.762	0.560	0.613	0.536	0.923
X(Cl)	0.023	0.010	0.022	0.015	0.005	0.031	0.019	0.030	0.023	0.024	0.024	0.026
X(OH)	0.435	0.626	0.493	0.339	0.649	0.280	0.500	0.208	0.417	0.363	0.440	0.052
Cl/Cl+F	0.040	0.026	0.044	0.022	0.013	0.044	0.038	0.038	0.040	0.038	0.042	0.027

Table B.3a (cont.)

OC7-1 Apatite Groundmass Compositions

	GM 13	*GM 14*	*GM 15*	*GM 16*	*GM 17*	*GM 18*	*GM 19*	*GM 20*
SiO2	1.24	1.40	0.37	0.52	0.25	0.35	0.31	0.21
FeO	0.68	0.63	0.71	0.61	0.73	0.56	0.55	0.59
MnO	0.07	0.05	0.06	0.04	0.04	0.06	0.03	0.04
MgO	0.83	1.03	0.68	0.73	0.54	0.62	0.63	0.74
CaO	52.07	52.43	52.76	53.17	53.38	53.10	53.21	53.54
P2O5	39.54	38.74	39.75	39.25	39.18	39.42	40.18	40.04
Na2O	0.05	0.05	0.05	0.04	0.05	0.03	0.06	0.04
SO3	0.39	0.57	0.42	0.35	0.62	0.48	0.44	0.38
F	2.30	1.94	3.06	2.73	1.87	2.09	2.60	1.76
Cl	0.17	0.16	0.14	0.16	0.08	0.10	0.14	0.05
Total	96.32	96.14	96.68	96.42	95.94	95.92	97.04	96.63
O=F,Cl	1.01	0.85	1.32	1.19	0.81	0.90	1.13	0.75
					Cations Based on 25 Oxygens			
Si	0.214	0.243	0.064	0.091	0.044	0.062	0.054	0.036
Fe	0.098	0.091	0.103	0.089	0.106	0.082	0.079	0.084
Mn	0.010	0.007	0.009	0.006	0.007	0.008	0.005	0.006
Mg	0.215	0.266	0.176	0.190	0.141	0.161	0.163	0.191
Ca	9.636	9.725	9.809	9.921	9.962	9.905	9.818	9.887
P	5.782	5.679	5.841	5.787	5.779	5.810	5.858	5.843
Na	0.016	0.015	0.016	0.014	0.018	0.011	0.019	0.014
S	0.050	0.074	0.055	0.046	0.081	0.063	0.057	0.049
F	1.258	1.063	1.680	1.506	1.032	1.153	1.418	0.962
Cl	0.050	0.047	0.040	0.046	0.022	0.029	0.040	0.013
Total	17.328	17.209	17.793	17.695	17.190	17.283	17.511	17.084
X(F)	0.629	0.532	0.840	0.753	0.516	0.576	0.709	0.481
X(Cl)	0.025	0.023	0.020	0.023	0.011	0.014	0.020	0.007
X(OH)	0.346	0.445	0.140	0.224	0.473	0.409	0.271	0.513
Cl/Cl+F	0.039	0.042	0.023	0.030	0.021	0.024	0.027	0.013

X(F)=F/2
X(Cl)=Cl/2
X(OH)=1-(X(F)+X(Cl))

Table B.3b

OC8-16 Groundmass Apatite Compositions

	CORE 1,1	*CORE 1,2*	*RIM 1,3*	*RIM 1,4*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*CORE 3,2*	*RIM 3,3*	*RIM 3,4*
SiO2	0.56	0.45	0.52	0.71	0.63	0.68	0.64	0.59	0.46	0.61	0.48	0.34
FeO	0.40	0.41	0.43	0.57	0.47	1.71	0.53	0.50	0.40	0.35	0.39	0.39
MnO	0.00	0.02	0.00	0.05	0.02	0.03	0.01	0.02	0.02	0.03	0.06	0.07
MgO	0.84	0.77	0.81	0.86	0.79	0.76	0.80	0.77	0.57	0.76	0.79	0.56
CaO	54.80	53.74	54.04	53.68	54.77	52.66	53.27	53.42	54.18	54.24	55.22	49.45
P2O5	41.59	41.41	42.00	41.53	41.49	39.92	41.05	41.05	38.04	40.93	42.34	41.51
Na2O	0.02	0.00	0.05	0.02	0.03	0.06	0.06	0.04	0.06	0.04	0.05	0.04
SO3	0.41	0.41	0.43	0.39	0.41	0.42	0.34	0.43	0.33	0.40	0.42	0.32
F	2.42	2.32	2.53	2.77	2.62	2.81	2.53	2.56	2.86	2.33	3.04	2.63
Cl	0.14	0.12	0.13	0.11	0.10	0.14	0.10	0.09	0.14	0.13	0.10	0.17
Total	100.12	98.64	99.85	99.49	100.20	97.97	98.23	98.36	95.82	98.80	101.58	94.33
O=F,Cl	1.05	1.00	1.09	1.19	1.13	1.21	1.09	1.10	1.24	1.01	1.30	1.14
					Cations Based on 25 Oxygens							
Si	0.093	0.076	0.087	0.118	0.105	0.116	0.108	0.100	0.082	0.103	0.079	0.059
Fe	0.056	0.058	0.060	0.080	0.065	0.246	0.075	0.070	0.059	0.049	0.053	0.057
Mn	0.001	0.003	0.000	0.007	0.002	0.005	0.002	0.003	0.003	0.004	0.008	0.010
Mg	0.207	0.192	0.202	0.215	0.196	0.193	0.202	0.194	0.150	0.190	0.193	0.146
Ca	9.760	9.690	9.622	9.616	9.762	9.670	9.661	9.675	10.256	9.793	9.714	9.230
P	5.854	5.900	5.909	5.879	5.843	5.793	5.882	5.875	5.691	5.840	5.885	6.122
Na	0.007	0.001	0.017	0.006	0.009	0.019	0.019	0.012	0.019	0.013	0.015	0.014
S	0.051	0.052	0.054	0.049	0.051	0.054	0.043	0.055	0.044	0.051	0.052	0.042
F	1.271	1.232	1.327	1.463	1.377	1.520	1.355	1.366	1.600	1.240	1.580	1.446
Cl	0.038	0.035	0.036	0.031	0.029	0.040	0.029	0.025	0.041	0.037	0.028	0.050
Total	17.338	17.238	17.314	17.463	17.440	17.657	17.376	17.375	17.945	17.319	17.605	17.176
X(F)	0.635	0.616	0.664	0.732	0.689	0.760	0.677	0.683	0.800	0.620	0.790	0.723
X(Cl)	0.019	0.018	0.018	0.015	0.015	0.020	0.015	0.012	0.020	0.019	0.014	0.025
X(OH)	0.346	0.366	0.318	0.253	0.297	0.220	0.308	0.305	0.180	0.362	0.196	0.252
Cl/Cl+F	0.029	0.028	0.026	0.021	0.021	0.026	0.021	0.018	0.025	0.029	0.017	0.033

Table B.3b (cont.)

OC8-16 Groundmass Apatite Compositions

	CORE 4,1	*CORE 4,2*	*RIM 4,3*	*RIM 4,4*	*CORE 5,1*	*CORE 5,2*	*RIM 5,3*	*RIM 5,4*
SiO2	0.82	0.93	0.85	0.84	0.69	0.59	0.63	0.70
FeO	0.50	0.59	0.56	0.57	0.56	0.48	0.50	0.54
MnO	0.06	0.07	0.09	0.03	0.05	0.04	0.07	0.05
MgO	0.72	0.79	0.76	0.75	0.56	0.85	0.83	0.85
CaO	54.14	53.53	54.17	54.04	53.90	54.04	54.28	53.66
P2O5	42.06	41.15	41.59	41.10	41.49	41.81	42.07	42.03
Na2O	0.05	0.06	0.06	0.07	0.09	0.06	0.05	0.03
SO3	0.49	0.41	0.37	0.45	0.38	0.42	0.42	0.50
F	3.23	3.01	2.93	3.23	3.16	2.92	2.81	2.86
Cl	0.24	0.30	0.29	0.19	0.25	0.15	0.35	0.14
Total	100.89	99.50	100.37	99.88	99.76	100.09	100.73	100.12
O=F,Cl	1.41	1.33	1.30	1.40	1.39	1.26	1.26	1.23
					Cations Based on 25 Oxygens			
Si	0.135	0.156	0.141	0.141	0.115	0.099	0.104	0.115
Fe	0.070	0.083	0.078	0.080	0.079	0.067	0.069	0.075
Mn	0.008	0.010	0.013	0.004	0.006	0.005	0.009	0.007
Mg	0.178	0.196	0.188	0.188	0.140	0.212	0.205	0.210
Ca	9.581	9.623	9.653	9.696	9.674	9.631	9.619	9.535
P	5.882	5.845	5.856	5.827	5.884	5.888	5.891	5.901
Na	0.015	0.020	0.019	0.022	0.031	0.018	0.015	0.010
S	0.060	0.052	0.046	0.057	0.048	0.053	0.052	0.062
F	1.688	1.597	1.542	1.710	1.676	1.536	1.469	1.498
Cl	0.067	0.085	0.082	0.055	0.072	0.041	0.097	0.040
Total	17.684	17.665	17.618	17.781	17.726	17.550	17.530	17.453
X(F)	0.844	0.798	0.771	0.855	0.838	0.768	0.734	0.749
X(Cl)	0.033	0.042	0.041	0.028	0.036	0.021	0.049	0.020
X(OH)	0.123	0.160	0.188	0.117	0.126	0.211	0.217	0.231
Cl/Cl+F	0.038	0.050	0.051	0.031	0.041	0.026	0.062	0.026

X(F)=F/2
X(Cl)=Cl/2
X(OH)=1-(X(F)+X(Cl))

Table B.3c

OC8-6 Apatite Compositions

	CORE 1,1	*CORE 1,2*	*RIM 1,3*	*RIM 1,4*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*RIM 3,3*	*RIM 3,4*	*CORE 4,1*
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.13	0.10	0.16	0.24	0.15	0.12	0.25	0.28	0.14	0.19	0.16	0.17
MnO	0.03	0.06	0.02	0.01	0.03	0.03	0.04	0.01	0.04	0.01	0.02	0.02
MgO	0.19	0.19	0.22	0.29	0.23	0.24	0.20	0.21	0.23	0.20	0.20	0.20
CaO	53.56	53.82	53.42	53.48	54.06	54.07	54.15	53.75	53.27	53.41	53.62	53.34
P2O5	40.61	40.93	41.06	39.00	41.07	39.48	40.62	41.01	40.81	40.95	40.49	40.63
Na2O	0.10	0.08	0.09	0.09	0.08	0.10	0.09	0.09	0.08	0.06	0.06	0.07
SO3	0.49	0.40	0.63	0.40	0.31	0.37	0.31	0.26	0.35	0.36	0.34	0.39
F	1.60	1.68	1.50	1.63	2.52	2.10	1.93	1.99	1.81	1.77	1.86	1.76
Cl	0.07	0.12	0.23	0.18	0.11	0.13	0.11	0.11	0.10	0.13	0.15	0.12
Total	96.08	96.65	96.65	94.59	97.48	95.71	96.84	96.84	96.03	96.31	96.09	95.93
O=F,Cl	0.69	0.73	0.68	0.73	1.08	0.91	0.84	0.86	0.78	0.77	0.82	0.77
Cations Based on 25 Oxygens												
Si	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.018	0.015	0.023	0.035	0.021	0.018	0.035	0.040	0.020	0.027	0.023	0.025
Mn	0.004	0.008	0.004	0.001	0.005	0.005	0.006	0.002	0.005	0.002	0.003	0.002
Mg	0.049	0.048	0.057	0.077	0.059	0.063	0.050	0.055	0.058	0.052	0.051	0.051
Ca	9.899	9.894	9.792	10.127	9.909	10.135	9.983	9.887	9.855	9.849	9.945	9.885
P	5.930	5.946	5.946	5.835	5.949	5.848	5.917	5.961	5.966	5.968	5.934	5.949
Na	0.033	0.026	0.029	0.032	0.026	0.033	0.029	0.030	0.028	0.019	0.020	0.024
S	0.063	0.052	0.081	0.053	0.040	0.048	0.040	0.033	0.045	0.047	0.044	0.051
F	0.874	0.910	0.813	0.908	1.362	1.161	1.049	1.081	0.988	0.963	1.015	0.964
Cl	0.019	0.036	0.066	0.055	0.032	0.037	0.032	0.031	0.029	0.039	0.044	0.036
Total	16.889	16.936	16.811	17.122	17.403	17.348	17.140	17.119	16.993	16.966	17.080	16.987
X(F)	0.437	0.455	0.406	0.454	0.681	0.581	0.524	0.540	0.494	0.481	0.508	0.482
X(Cl)	0.010	0.018	0.033	0.028	0.016	0.019	0.016	0.015	0.015	0.019	0.022	0.018
X(OH)	0.553	0.527	0.561	0.518	0.303	0.401	0.460	0.444	0.492	0.499	0.470	0.500
Cl/Cl+F	0.022	0.038	0.075	0.057	0.023	0.031	0.030	0.028	0.029	0.039	0.042	0.036

Table B.3c (cont.)

OC8-6 Apatite Compositions

	CORE 4,2	*RIM 4,3*	*RIM 4,4*	*CORE 5,1*	*CORE 5,2*	*RIM 5,3*	*RIM 5,4*	*CORE 6,1*	*CORE 6,2*	*RIM 6,3*	*RIM 6,4*
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.18	0.31	0.25	0.13	0.11	0.17	0.17	0.14	0.18	0.20	0.24
MnO	0.02	0.02	0.04	0.04	0.03	0.03	0.02	0.03	0.04	0.01	0.03
MgO	0.29	0.35	0.17	0.22	0.18	0.20	0.21	0.23	0.24	0.20	0.27
CaO	53.37	52.82	54.13	54.01	53.95	53.56	53.56	53.02	52.95	53.77	52.90
P2O5	39.71	41.02	40.72	40.34	37.35	40.80	40.39	39.88	40.79	39.76	41.08
Na2O	0.11	0.08	0.07	0.13	0.11	0.08	0.10	0.06	0.07	0.06	0.09
SO3	0.57	0.44	0.44	0.62	0.47	0.54	0.50	0.48	0.47	0.45	0.49
F	1.75	1.75	1.68	1.61	1.68	1.59	1.54	1.59	1.52	1.67	1.46
Cl	0.12	0.12	0.12	0.12	0.10	0.16	0.11	0.12	0.12	0.10	0.14
Total	95.35	96.13	96.88	96.52	93.26	96.41	95.93	94.86	95.71	95.49	96.03
O=F,Cl	0.77	0.77	0.73	0.71	0.73	0.71	0.68	0.70	0.66	0.73	0.64
Cations Based on 25 Oxygens											
Si	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.027	0.044	0.036	0.018	0.017	0.025	0.025	0.020	0.025	0.029	0.034
Mn	0.003	0.003	0.005	0.006	0.005	0.005	0.003	0.005	0.006	0.001	0.004
Mg	0.074	0.089	0.043	0.057	0.049	0.051	0.055	0.060	0.062	0.052	0.068
Ca	9.983	9.739	9.950	9.960	10.440	9.861	9.923	9.942	9.800	10.051	9.743
P	5.869	5.977	5.914	5.878	5.712	5.936	5.913	5.909	5.965	5.872	5.979
Na	0.036	0.028	0.023	0.042	0.038	0.026	0.035	0.021	0.023	0.022	0.028
S	0.074	0.057	0.056	0.081	0.064	0.069	0.064	0.064	0.061	0.059	0.063
F	0.967	0.955	0.910	0.878	0.959	0.864	0.844	0.878	0.828	0.924	0.791
Cl	0.037	0.035	0.035	0.036	0.029	0.047	0.033	0.037	0.035	0.029	0.041
Total	17.070	16.925	16.973	16.956	17.312	16.882	16.896	16.935	16.805	17.038	16.752
X(F)	0.483	0.477	0.455	0.439	0.480	0.432	0.422	0.439	0.414	0.462	0.396
X(Cl)	0.018	0.018	0.017	0.018	0.015	0.023	0.016	0.018	0.018	0.015	0.021
X(OH)	0.498	0.505	0.528	0.543	0.506	0.545	0.561	0.543	0.569	0.524	0.584
Cl/Cl+F	0.037	0.035	0.037	0.039	0.029	0.051	0.037	0.040	0.041	0.031	0.049

X(F)=F/2
X(Cl)=Cl/2
X(OH)=1-(X(F)+X(Cl))

Table B.3d

OC8-9 Apatite Compositions

	CORE 1,1	*CORE 1,2*	*RIM 1,3*	*RIM 1,4*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*CORE 3,2*	*RIM 3,3*	*RIM 3,4*
SiO2	0.26	0.22	0.16	0.22	0.34	0.34	0.28	0.29	0.24	0.15	0.23	0.19
FeO	0.15	0.18	0.17	0.17	0.16	0.17	0.16	0.14	0.15	0.19	0.35	0.28
MnO	0.04	0.02	0.04	0.04	0.05	0.04	0.04	0.02	0.02	0.06	0.04	0.05
MgO	0.37	0.39	0.32	0.37	0.44	0.44	0.28	0.27	0.35	0.37	0.75	0.40
CaO	53.04	52.64	52.78	52.94	53.87	55.00	53.32	53.52	53.42	53.59	53.70	53.56
P2O5	41.11	41.19	41.79	41.48	40.85	41.85	41.22	41.95	41.97	42.16	41.66	41.57
Na2O	0.18	0.20	0.19	0.18	0.14	0.11	0.13	0.09	0.13	0.18	0.16	0.22
SO3	0.45	0.58	0.55	0.49	0.47	0.41	0.49	0.50	0.52	0.46	0.41	0.48
F	2.37	2.07	2.10	2.08	2.53	2.55	2.15	2.15	2.13	2.17	2.18	2.11
Cl	0.20	0.13	0.18	0.19	0.13	0.14	0.16	0.15	0.20	0.13	0.15	0.18
Total	97.12	96.73	97.36	97.23	97.88	99.94	97.27	98.16	98.20	98.51	98.67	98.10
O=F,Cl	1.04	0.90	0.93	0.92	1.09	1.11	0.94	0.94	0.94	0.94	0.95	0.93
						Cations Based on 25 Oxygens						
Si	0.044	0.038	0.028	0.038	0.058	0.057	0.047	0.049	0.041	0.025	0.039	0.033
Fe	0.022	0.026	0.024	0.024	0.023	0.024	0.023	0.020	0.021	0.026	0.049	0.040
Mn	0.006	0.003	0.006	0.005	0.007	0.005	0.006	0.003	0.003	0.009	0.005	0.007
Mg	0.094	0.099	0.082	0.094	0.111	0.110	0.071	0.068	0.089	0.093	0.188	0.101
Ca	9.714	9.639	9.591	9.649	9.824	9.819	9.734	9.656	9.635	9.639	9.673	9.699
P	5.950	5.960	6.000	5.974	5.886	5.903	5.946	5.981	5.981	5.993	5.930	5.949
Na	0.059	0.066	0.064	0.058	0.046	0.036	0.042	0.030	0.043	0.060	0.051	0.072
S	0.057	0.075	0.070	0.062	0.060	0.051	0.062	0.063	0.066	0.057	0.052	0.061
F	1.279	1.118	1.129	1.121	1.360	1.345	1.159	1.147	1.132	1.153	1.158	1.126
Cl	0.057	0.037	0.053	0.054	0.038	0.040	0.045	0.044	0.057	0.037	0.043	0.052
Total	17.281	17.061	17.046	17.081	17.414	17.390	17.134	17.060	17.066	17.091	17.188	17.138
X(F)	0.639	0.559	0.564	0.560	0.680	0.672	0.579	0.574	0.566	0.577	0.579	0.563
X(Cl)	0.028	0.019	0.026	0.027	0.019	0.020	0.023	0.022	0.028	0.019	0.022	0.026
X(OH)	0.333	0.422	0.409	0.413	0.301	0.308	0.398	0.405	0.406	0.405	0.400	0.411
Cl/Cl+F	0.042	0.032	0.045	0.046	0.027	0.029	0.037	0.037	0.048	0.031	0.036	0.044

Table B.3d (cont.)

OC8-9 Apatite Compositions

	CORE 4,1	*CORE 4,2*	*RIM 4,3*	*RIM 4,4*	*CORE 5,1*	*CORE 5,2*	*RIM 5,3*	*RIM 5,4*
SiO2	0.33	0.37	0.31	0.28	0.19	0.25	0.24	0.22
FeO	0.19	0.19	0.23	0.26	0.19	0.19	0.22	0.28
MnO	0.07	0.06	0.06	0.07	0.05	0.02	0.03	0.01
MgO	0.40	0.39	0.40	0.41	0.42	0.35	0.40	0.56
CaO	53.10	53.19	52.99	53.05	52.82	52.42	52.52	53.32
P2O5	41.84	42.18	41.34	41.71	41.84	41.55	41.41	40.93
Na2O	0.04	0.06	0.06	0.03	0.16	0.10	0.13	0.13
SO3	0.14	0.19	0.21	0.16	0.49	0.42	0.53	0.49
F	1.96	1.96	2.02	2.12	2.06	2.08	2.02	1.97
Cl	0.15	0.17	0.17	0.17	0.15	0.13	0.17	0.18
Total	97.37	97.89	96.90	97.33	97.45	96.59	96.78	97.22
O=F,Cl	0.86	0.86	0.89	0.93	0.90	0.90	0.89	0.87
					Cations Based on 25 Oxygens			
Si	0.056	0.063	0.054	0.048	0.032	0.042	0.042	0.038
Fe	0.027	0.027	0.032	0.037	0.026	0.027	0.031	0.039
Mn	0.010	0.009	0.009	0.009	0.007	0.003	0.004	0.002
Mg	0.102	0.098	0.103	0.105	0.105	0.089	0.101	0.142
Ca	9.657	9.608	9.703	9.669	9.587	9.595	9.601	9.749
P	6.013	6.020	5.983	6.007	6.000	6.010	5.982	5.913
Na	0.014	0.019	0.021	0.010	0.051	0.033	0.042	0.043
S	0.017	0.025	0.026	0.021	0.062	0.054	0.068	0.063
F	1.051	1.047	1.090	1.141	1.106	1.121	1.089	1.063
Cl	0.043	0.047	0.050	0.048	0.044	0.039	0.050	0.051
Total	16.990	16.962	17.071	17.094	17.019	17.013	17.011	17.103
X(F)	0.525	0.524	0.545	0.571	0.553	0.561	0.545	0.532
X(Cl)	0.021	0.024	0.025	0.024	0.022	0.019	0.025	0.026
X(OH)	0.453	0.453	0.430	0.405	0.425	0.420	0.430	0.443
Cl/Cl+F	0.039	0.043	0.044	0.040	0.038	0.033	0.044	0.046

X(F)=F/2
X(Cl)=Cl/2
X(OH)=1-(X(F)+X(Cl))

Table B.3e

OC 8-17 Apatite Compositions

	CORE 1,1	*CORE 1,2*	*RIM 1,3*	*RIM 1,4*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*CORE 3,2*	*RIM 3,3*	*RIM 3,4*
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.10	0.13	0.26	0.18	0.22	0.16	0.21	0.19	0.15	0.11	0.16	0.22
MnO	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.06	0.04	0.07	0.05	0.04
MgO	0.15	0.11	0.33	0.17	0.20	0.16	0.31	0.19	0.17	0.15	0.10	0.23
CaO	53.65	53.73	51.92	52.52	52.73	53.28	53.05	54.10	53.08	52.30	52.08	53.61
P2O5	40.64	40.25	39.18	40.04	38.88	40.36	39.81	40.55	39.92	40.17	39.95	40.54
Na2O	0.04	0.08	0.08	0.09	0.03	0.08	0.02	0.03	0.03	0.01	0.04	0.03
SO3	0.41	0.32	0.41	0.57	0.39	0.27	0.22	0.28	0.30	0.35	0.31	0.26
F	1.90	1.79	1.60	1.77	1.96	1.96	1.90	1.88	1.51	1.55	1.52	1.45
Cl	0.12	0.23	0.14	0.17	0.20	0.15	0.12	0.13	0.15	0.15	0.22	0.15
Total	96.23	95.88	93.26	94.78	93.77	95.60	94.85	96.57	94.66	94.17	93.73	95.89
O=F,Cl	0.83	0.80	0.70	0.79	0.87	0.86	0.83	0.82	0.67	0.69	0.69	0.64
Cations Based on 25 Oxygens												
Si	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.015	0.019	0.039	0.026	0.033	0.023	0.030	0.028	0.022	0.017	0.023	0.032
Mn	0.007	0.008	0.007	0.006	0.006	0.007	0.008	0.008	0.005	0.010	0.008	0.006
Mg	0.039	0.029	0.086	0.044	0.052	0.042	0.080	0.048	0.043	0.040	0.027	0.060
Ca	9.924	10.005	9.912	9.849	10.074	9.939	9.986	9.999	9.981	9.850	9.864	9.944
P	5.940	5.921	5.911	5.934	5.870	5.948	5.922	5.922	5.931	5.977	5.979	5.941
Na	0.013	0.026	0.028	0.032	0.010	0.026	0.006	0.009	0.009	0.004	0.015	0.009
S	0.054	0.041	0.055	0.075	0.052	0.035	0.029	0.036	0.039	0.046	0.041	0.033
F	1.035	0.983	0.899	0.982	1.105	1.081	1.057	1.025	0.839	0.860	0.849	0.793
Cl	0.035	0.067	0.042	0.051	0.059	0.043	0.035	0.038	0.044	0.045	0.066	0.045
Total	17.061	17.099	16.980	16.999	17.260	17.144	17.154	17.112	16.913	16.849	16.871	16.864
X(F)	0.518	0.491	9.450	0.491	0.552	0.540	0.529	0.513	0.420	0.430	0.425	0.397
X(Cl)	0.018	0.034	0.021	0.026	0.030	0.022	0.017	0.019	0.022	0.023	0.033	0.023
X(OH)	0.465	0.475	0.529	0.483	0.418	0.438	0.454	0.469	0.558	0.547	0.543	0.581
Cl/Cl+F	0.033	0.064	0.045	0.050	0.051	0.038	0.032	0.035	0.050	0.050	0.072	0.054

Table B.3e (cont.)

OC 8-17 Apatite Compositions

	CORE 4,1	*CORE 4,2*	*RIM 4,3*	*RIM 4,4*	*CORE 5,1*	*CORE 5,2*	*RIM 5,3*	*RIM 5,4*	*CORE 6,1*	*RIM 6,3*	*RIM 6,4*
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.16	0.14	0.16	0.16	0.12	0.13	0.20	0.22	0.12	0.30	0.19
MnO	0.06	0.05	0.07	0.03	0.04	0.04	0.04	0.02	0.03	0.00	0.04
MgO	0.15	0.13	0.18	0.19	0.12	0.12	0.64	0.30	0.16	0.63	0.09
CaO	53.85	54.11	53.62	53.92	53.47	53.10	53.55	52.64	53.48	52.50	53.48
P2O5	40.56	41.06	40.61	41.02	41.03	39.66	40.37	40.60	40.48	40.22	40.48
Na2O	0.04	0.06	0.04	0.05	0.06	0.04	0.02	0.08	0.07	0.09	0.07
SO3	0.27	0.29	0.20	0.24	0.45	0.21	0.23	0.48	0.46	0.42	0.35
F	1.99	1.84	1.98	1.92	1.64	1.67	1.38	1.38	1.61	1.47	1.66
Cl	0.16	0.13	0.13	0.13	0.18	0.18	0.17	0.14	0.16	0.17	0.22
Total	96.37	97.00	96.12	96.82	96.38	94.40	95.98	95.25	95.86	95.13	95.82
O=F,Cl	0.88	0.80	0.86	0.84	0.73	0.74	0.62	0.61	0.71	0.66	0.75
Cations Based on 25 Oxygens											
Si	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.023	0.020	0.023	0.023	0.017	0.020	0.029	0.032	0.017	0.043	0.027
Mn	0.009	0.008	0.010	0.005	0.006	0.005	0.005	0.003	0.004	0.000	0.005
Mg	0.040	0.033	0.047	0.048	0.031	0.031	0.165	0.078	0.042	0.163	0.024
Ca	9.975	9.930	9.951	9.918	9.842	10.041	9.925	9.783	9.917	9.794	9.939
P	5.937	5.955	5.955	5.962	5.968	5.926	5.913	5.961	5.932	5.929	5.943
Na	0.012	0.021	0.013	0.015	0.019	0.014	0.007	0.028	0.025	0.029	0.024
S	0.035	0.038	0.025	0.031	0.058	0.027	0.030	0.062	0.060	0.055	0.045
F	1.090	0.994	1.086	1.040	0.889	0.929	0.754	0.759	0.881	0.808	0.909
Cl	0.048	0.037	0.039	0.039	0.053	0.055	0.051	0.040	0.046	0.050	0.065
Total	17.168	17.034	17.148	17.082	16.883	17.048	16.879	16.745	16.922	16.870	16.981
X(F)	0.545	0.497	0.543	0.520	0.444	0.465	0.377	0.379	0.440	0.404	0.455
X(Cl)	0.024	0.018	0.019	0.019	0.026	0.027	0.025	0.020	0.023	0.025	0.032
X(OH)	0.431	0.485	0.438	0.461	0.529	0.508	0.597	0.601	0.537	0.571	0.513
Cl/Cl+F	0.042	0.036	0.034	0.036	0.056	0.056	0.063	0.050	0.049	0.058	0.066

X(F)=F/2
X(Cl)=Cl/2
X(OH)=1-(X(F)+X(Cl))

Table B.3f

AU26-5 Apatite Compositions

	CORE 1,1	*CORE 1,2*	*RIM 1,3*	*RIM 1,4*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*CORE 3,2*	*RIM 3,3*	*RIM 3,4*
SiO2	0.42	0.45	0.27	0.41	0.36	0.29	0.30	0.28	0.34	0.40	0.30	0.32
FeO	0.19	0.18	0.15	0.21	0.11	0.11	0.18	0.32	0.22	0.26	0.36	0.29
MnO	0.04	0.05	0.04	0.03	0.04	0.05	0.09	0.06	0.07	0.05	0.04	0.07
MgO	0.51	0.52	0.30	0.45	0.18	0.14	0.36	0.34	0.63	0.88	0.90	0.53
CaO	55.61	54.63	54.99	54.27	53.89	54.72	54.08	54.33	54.81	54.24	54.83	54.51
P2O5	40.55	41.52	40.57	41.08	40.87	42.24	41.21	42.24	42.59	41.51	43.03	42.11
Na2O	0.05	0.03	0.03	0.04	0.02	0.04	0.05	0.06	0.02	0.05	0.07	0.07
SO3	0.29	0.33	0.25	0.33	0.32	0.27	0.30	0.31	0.30	0.34	0.25	0.37
F	1.56	2.26	2.24	2.45	2.29	2.24	2.24	2.25	2.05	2.02	2.34	2.40
Cl	0.07	0.08	0.07	0.10	0.09	0.06	0.09	0.06	0.07	0.09	0.09	0.08
Total	98.62	99.07	97.96	98.32	97.18	99.21	97.93	99.27	100.22	98.97	101.20	99.72
O=F,Cl	0.67	0.97	0.96	1.05	0.98	0.96	0.96	0.96	0.88	0.87	1.01	1.03
Cations Based on 25 Oxygens												
Si	0.071	0.076	0.046	0.070	0.061	0.049	0.051	0.046	0.057	0.068	0.049	0.054
Fe	0.027	0.026	0.022	0.029	0.016	0.015	0.025	0.045	0.031	0.037	0.049	0.041
Mn	0.005	0.007	0.006	0.005	0.005	0.007	0.012	0.008	0.010	0.008	0.006	0.010
Mg	0.130	0.129	0.076	0.114	0.045	0.035	0.091	0.084	0.155	0.219	0.218	0.132
Ca	10.071	9.817	10.051	9.850	9.881	9.797	9.837	9.720	9.696	9.742	9.617	9.723
P	5.803	5.897	5.860	5.891	5.921	5.976	5.923	5.971	5.953	5.890	5.964	5.935
Na	0.015	0.011	0.011	0.013	0.007	0.014	0.017	0.020	0.006	0.015	0.022	0.022
S	0.037	0.041	0.032	0.043	0.042	0.034	0.039	0.038	0.037	0.042	0.031	0.046
F	0.833	1.197	1.208	1.312	1.237	1.185	1.203	1.187	1.070	1.072	1.211	1.264
Cl	0.019	0.022	0.021	0.028	0.026	0.016	0.027	0.017	0.021	0.026	0.025	0.023
Total	17.011	17.222	17.333	17.356	17.240	17.128	17.225	17.135	17.034	17.118	17.190	17.250
X(F)	0.417	0.598	0.604	0.656	0.618	0.593	0.602	0.593	0.535	0.536	0.605	0.632
X(Cl)	0.009	0.011	0.010	0.014	0.013	0.008	0.013	0.009	0.010	0.013	0.013	0.012
X(OH)	0.574	0.391	0.386	0.330	0.369	0.399	0.385	0.398	0.455	0.451	0.382	0.356
Cl/Cl+F	0.022	0.018	0.017	0.021	0.020	0.013	0.022	0.014	0.019	0.024	0.020	0.018

Table B.3f (cont.)

AU26-5 Apatite Compositions

	CORE 4,1	*CORE 4,2*	*RIM 4,3*	*RIM 4,4*	*CORE 5,1*	*CORE 5,2*	*RIM 5,3*	*RIM 5,4*
SiO2	0.38	0.41	0.46	0.36	0.28	0.33	0.32	0.11
FeO	0.23	0.25	0.31	0.25	0.20	0.23	0.28	0.08
MnO	0.04	0.05	0.04	0.01	0.05	0.04	0.05	0.03
MgO	0.98	0.88	0.83	0.73	0.75	0.90	0.49	0.06
CaO	54.59	54.82	54.58	55.26	54.27	54.32	54.54	55.11
P2O5	41.59	41.71	42.50	41.77	42.39	41.53	41.72	42.60
Na2O	0.06	0.05	0.05	0.04	0.07	0.04	0.07	0.09
SO3	0.36	0.30	0.32	0.26	0.23	0.20	0.34	0.11
F	2.18	2.26	2.28	2.30	2.05	2.26	2.48	2.44
Cl	0.09	0.11	0.09	0.07	0.07	0.06	0.08	0.06
Total	99.56	99.86	100.47	100.06	99.49	98.94	99.29	99.65
O=F,Cl	0.94	0.98	0.98	0.98	0.88	0.96	1.06	1.04
Cations Based on 25 Oxygens								
Si	0.063	0.069	0.075	0.060	0.046	0.055	0.053	0.019
Fe	0.033	0.035	0.042	0.034	0.028	0.033	0.039	0.011
Mn	0.006	0.007	0.005	0.002	0.008	0.006	0.007	0.005
Mg	0.243	0.219	0.204	0.180	0.187	0.226	0.121	0.015
Ca	9.761	9.781	9.642	9.851	9.668	9.778	9.791	9.844
P	5.876	5.881	5.933	5.884	5.968	5.907	5.919	6.013
Na	0.019	0.016	0.016	0.014	0.022	0.013	0.021	0.028
S	0.045	0.037	0.039	0.032	0.029	0.025	0.043	0.014
F	1.152	1.191	1.187	1.209	1.079	1.199	1.316	1.286
Cl	0.025	0.030	0.025	0.019	0.020	0.017	0.022	0.016
Total	17.220	17.265	17.167	17.285	17.053	17.258	17.332	17.250
X(F)	0.576	0.596	0.593	0.605	0.539	0.600	0.658	0.643
X(Cl)	0.012	0.015	0.012	0.010	0.010	0.009	0.011	0.008
X(OH)	0.412	0.389	0.394	0.386	0.451	0.392	0.331	0.349
Cl/Cl+F	0.021	0.024	0.020	0.016	0.018	0.014	0.017	0.012

X(F)=F/2
X(Cl)=Cl/2
X(OH)=1-(X(F)+X(Cl))

Table B.3g
AU26-10 Apatite Compositions

	CORE 1,1	*CORE 1,2*	*RIM 1,3*	*RIM 1,4*	*CORE 2,1*	*CORE 2,2*	*RIM 2,3*	*RIM 2,4*	*CORE 3,1*	*CORE 3,2*	*RIM 3,3*	*RIM 3,4*
SiO2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	0.26	0.26	0.29	0.20	0.23	0.23	0.25	0.28	0.28	0.22	0.29	0.40
MnO	0.03	0.04	0.05	0.00	0.04	0.04	0.05	0.07	0.07	0.04	0.03	0.03
MgO	0.63	0.54	0.37	0.71	0.36	0.29	0.58	0.44	0.56	0.61	0.81	0.65
CaO	53.56	53.27	53.72	53.77	53.49	53.59	53.41	53.28	53.56	53.52	52.90	53.29
P2O5	40.36	40.66	40.74	41.31	40.23	40.05	40.89	40.21	40.78	40.42	39.69	40.83
Na2O	0.04	0.05	0.05	0.03	0.06	0.05	0.05	0.03	0.02	0.04	0.02	0.02
SO3	0.26	0.24	0.33	0.39	0.45	0.49	0.35	0.31	0.37	0.36	0.36	0.27
F	1.72	1.74	1.54	1.54	1.70	1.62	1.51	1.69	1.52	1.64	1.32	1.56
Cl	0.12	0.13	0.13	0.10	0.17	0.20	0.21	0.20	0.17	0.20	0.17	0.18
Total	96.21	96.16	96.53	97.37	95.97	95.84	96.63	95.77	96.66	96.30	95.00	96.52
O=F,Cl	0.75	0.76	0.68	0.67	0.75	0.73	0.68	0.76	0.68	0.73	0.60	0.70
					Cations Based on 25 Oxygens							
Si	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Fe	0.037	0.038	0.041	0.028	0.034	0.034	0.036	0.040	0.041	0.032	0.042	0.057
Mn	0.004	0.005	0.007	0.000	0.005	0.006	0.007	0.010	0.011	0.006	0.005	0.004
Mg	0.161	0.140	0.095	0.180	0.093	0.075	0.149	0.115	0.143	0.156	0.211	0.167
Ca	9.920	9.855	9.896	9.787	9.929	9.967	9.816	9.919	9.849	9.896	9.910	9.813
P	5.908	5.944	5.930	5.941	5.901	5.887	5.939	5.915	5.925	5.905	5.875	5.941
Na	0.012	0.015	0.015	0.010	0.020	0.016	0.018	0.011	0.008	0.013	0.007	0.006
S	0.034	0.031	0.043	0.049	0.059	0.064	0.045	0.041	0.047	0.047	0.047	0.035
F	0.939	0.949	0.836	0.827	0.932	0.891	0.817	0.927	0.824	0.893	0.732	0.845
Cl	0.036	0.037	0.038	0.029	0.049	0.059	0.061	0.059	0.050	0.057	0.050	0.052
Total	17.051	17.014	16.901	16.851	17.021	16.999	16.888	17.037	16.896	17.005	16.879	16.919
X(F)	0.470	0.475	0.418	0.414	0.466	0.446	0.408	0.463	0.412	0.446	0.366	0.423
X(Cl)	0.018	0.018	0.019	0.014	0.024	0.029	0.031	0.030	0.025	0.029	0.025	0.026
X(OH)	0.513	0.507	0.563	0.572	0.510	0.525	0.561	0.507	0.563	0.525	0.609	0.551
Cl/Cl+F	0.037	0.037	0.043	0.034	0.050	0.062	0.070	0.060	0.057	0.060	0.064	0.058

Table B.3g (cont.)
AU26-10 Apatite Compositions

	CORE 4,1	*CORE 4,2*	*RIM 4,3*	*RIM 4,4*	*CORE 5,1*	*CORE 5,2*	*RIM 5,3*	*RIM 5,4*	*CORE 6,1*	*CORE 6,2*	*RIM 6,3*	*RIM 6,4*
SiO2	0.11	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
FeO	0.29	0.22	0.30	0.22	0.21	0.21	0.26	0.20	0.24	0.21	0.30	0.37
MnO	0.02	0.06	0.06	0.09	0.06	0.06	0.06	0.02	0.06	0.04	0.05	0.06
MgO	0.59	0.26	0.51	0.38	0.48	0.40	0.72	0.74	0.39	0.40	0.76	0.43
CaO	53.29	53.40	53.11	53.06	53.89	53.67	53.44	53.47	53.80	53.24	53.98	54.12
P2O5	39.42	39.94	39.33	40.45	40.44	40.27	39.34	41.05	40.60	40.07	41.23	40.23
Na2O	0.01	0.04	0.04	0.06	0.03	0.04	0.03	0.05	0.04	0.03	0.03	0.04
SO3	0.39	0.43	0.34	0.29	0.40	0.30	0.21	0.25	0.37	0.31	0.22	0.25
F	1.90	1.60	1.74	1.75	1.67	1.62	1.64	1.49	1.73	1.66	1.51	1.57
Cl	0.17	0.15	0.20	0.20	0.18	0.16	0.19	0.16	0.20	0.14	0.08	0.22
Total	95.35	95.79	94.84	95.72	96.62	96.02	95.16	96.78	96.73	95.37	97.49	96.58
O=F,Cl	0.84	0.71	0.78	0.78	0.75	0.72	0.73	0.67	0.77	0.73	0.65	0.71
					Cations Based on 25 Oxygens							
Si	0.020	0.068	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000
Fe	0.042	0.032	0.044	0.032	0.030	0.031	0.039	0.029	0.034	0.030	0.042	0.053
Mn	0.003	0.008	0.009	0.014	0.009	0.009	0.009	0.003	0.009	0.007	0.007	0.009
Mg	0.153	0.068	0.133	0.098	0.123	0.104	0.189	0.189	0.099	0.103	0.192	0.112
Ca	9.997	9.922	10.017	9.869	9.942	9.964	10.054	9.805	9.910	9.946	9.833	10.016
P	5.844	5.864	5.862	5.945	5.894	5.908	5.849	5.948	5.910	5.915	5.935	5.883
Na	0.004	0.014	0.013	0.021	0.010	0.012	0.009	0.017	0.014	0.011	0.010	0.015
S	0.051	0.057	0.045	0.038	0.052	0.039	0.028	0.032	0.047	0.040	0.028	0.032
F	1.049	0.880	0.966	0.960	0.912	0.885	0.913	0.809	0.941	0.918	0.810	0.857
Cl	0.052	0.043	0.061	0.060	0.054	0.048	0.055	0.047	0.059	0.041	0.022	0.064
Total	17.215	16.953	17.150	17.037	17.026	17.001	17.143	16.878	17.036	17.011	16.880	17.040
X(F)	0.525	0.440	0.483	0.480	0.456	0.443	0.456	0.404	0.470	0.459	0.405	0.429
X(Cl)	0.026	0.021	0.030	0.030	0.027	0.024	0.028	0.024	0.030	0.020	0.011	0.032
X(OH)	0.450	0.539	0.487	0.490	0.517	0.533	0.516	0.572	0.500	0.521	0.584	0.539
Cl/Cl+F	0.047	0.046	0.059	0.059	0.056	0.052	0.057	0.055	0.059	0.042	0.027	0.070

X(F)=F/2
X(Cl)=Cl/2
X(OH)=1-(X(F)+X(Cl))

Table B.4a

OC7-1 Groundmass Alkali Feldspar Compositions

	GM 1	*GM 2*	*GM 4*	*GM 5*	*GM 6*	*GM 7*	*GM 8*	*GM 9*	*GM 10*	*GM 11*	*GM 12*	*GM 13*
SiO2	62.54	62.50	63.85	64.53	64.04	65.10	61.70	63.63	64.69	63.94	65.30	63.78
Al2O3	18.63	19.37	18.78	18.49	18.47	18.62	20.04	19.49	19.01	18.36	18.56	18.55
FeO	0.54	0.82	0.49	0.47	0.75	0.54	1.03	0.63	0.89	0.75	0.80	0.82
MnO	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.02
CaO	0.84	0.50	0.55	0.20	0.24	0.41	0.62	0.60	0.36	0.20	0.17	0.29
BaO	0.63	1.09	0.10	0.09	0.12	0.00	3.00	0.06	0.24	0.31	0.10	0.26
Na2O	1.55	3.70	3.52	3.41	2.82	3.33	3.56	3.74	3.37	3.06	3.12	3.23
K2O	13.90	10.53	11.39	11.86	12.08	11.56	9.45	11.07	11.58	11.98	12.12	11.51
Total	98.66	98.56	98.68	99.05	98.52	99.56	99.40	99.22	100.15	98.63	100.18	98.46
					Cations Based on 8 Oxygens							
Si	2.943	2.920	2.959	2.979	2.977	2.983	2.886	2.933	2.960	2.975	2.984	2.967
Al	1.033	1.067	1.026	1.006	1.012	1.006	1.105	1.058	1.025	1.007	1.000	1.017
Fe	0.021	0.032	0.019	0.018	0.029	0.021	0.040	0.024	0.034	0.029	0.031	0.032
Mn	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001
Ca	0.042	0.025	0.027	0.010	0.012	0.020	0.031	0.029	0.018	0.010	0.008	0.015
Ba	0.012	0.020	0.002	0.002	0.002	0.000	0.055	0.001	0.004	0.006	0.002	0.005
Na	0.142	0.335	0.316	0.306	0.254	0.296	0.323	0.335	0.299	0.276	0.277	0.291
K	0.834	0.628	0.673	0.698	0.716	0.676	0.564	0.651	0.676	0.711	0.706	0.683
XAN	0.04	0.02	0.03	0.01	0.01	0.02	0.03	0.03	0.02	0.01	0.01	0.01
XAB	0.14	0.33	0.31	0.30	0.26	0.30	0.33	0.33	0.30	0.28	0.28	0.29
XCS	0.01	0.02	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.01	0.00	0.00
XKS	0.81	0.62	0.66	0.69	0.73	0.68	0.58	0.64	0.68	0.71	0.71	0.69
(X)	1.03	1.01	1.02	1.02	0.98	0.99	0.97	1.02	1.00	1.00	0.99	0.99
(Z)	3.98	3.99	3.99	3.99	3.99	3.99	3.99	3.99	3.98	3.98	3.98	3.98

Table B.4a (cont.)

OC7-1 Groundmass Alkali Feldspar Compositions

	GM 15	*GM 20*	*GM 21*	*GM 22*
SiO2	64.24	63.76	63.13	63.87
Al2O3	18.54	19.09	18.75	18.75
FeO	0.79	0.79	0.85	0.66
MnO	0.00	0.00	0.00	0.01
CaO	0.39	0.47	0.26	0.20
BaO	0.10	0.73	0.03	0.28
Na2O	3.35	3.52	2.86	3.30
K2O	11.68	10.79	12.37	11.44
Total	99.09	99.15	98.25	98.51
				Cations Based on 8 Oxygens
Si	2.969	2.948	2.952	2.966
Al	1.010	1.040	1.033	1.026
Fe	0.030	0.031	0.033	0.026
Mn	0.000	0.000	0.000	0.000
Ca	0.019	0.023	0.013	0.010
Ba	0.002	0.013	0.001	0.005
Na	0.300	0.315	0.259	0.297
K	0.689	0.637	0.738	0.678
XAN	0.02	0.02	0.01	0.01
XAB	0.30	0.32	0.26	0.30
XCS	0.00	0.01	0.00	0.01
XKS	0.68	0.64	0.73	0.69
(X)	1.01	0.99	1.01	0.99
(Z)	3.98	3.99	3.99	3.99

X=Ca+Ba+Na+K
Z=Si+Al

Table B.4b

OC8-16 Groundmass Alkali Feldspar Compositions

	GM 1	*GM 2*	*GM 3*	*GM 5,1*	*GM 5,2*	*GM 6*	*GM 7*	*GM 8*	*GM 9*	*GM 10*	*GM 11*	*GM 12*
SiO2	64.55	64.36	65.04	62.07	64.99	64.30	64.55	63.71	64.71	64.50	65.08	65.08
Al2O3	16.77	18.96	18.66	17.38	18.98	18.61	18.91	19.95	18.86	19.19	18.68	18.57
FeO	1.33	0.90	0.68	1.33	0.68	0.80	0.58	0.54	1.01	0.54	0.55	0.62
MnO	0.04	0.00	0.00	0.02	0.00	0.00	0.07	0.00	0.00	0.01	0.04	0.02
CaO	3.10	0.77	0.27	4.16	0.40	0.33	0.30	1.01	0.41	0.49	0.42	0.31
BaO	0.05	0.81	0.70	0.14	0.37	0.47	0.56	0.90	0.35	1.14	0.83	0.26
Na2O	4.08	4.69	4.39	4.15	4.34	3.87	3.98	4.92	4.42	3.48	3.92	3.72
K2O	9.63	9.10	9.98	9.57	9.59	10.51	10.38	8.60	9.95	10.81	10.67	10.88
Total	99.55	99.59	99.72	98.82	99.35	98.89	99.33	99.63	99.71	100.16	100.19	99.46
Cations Based on 8 Oxygens												
Si	2.979	2.951	2.976	2.910	2.971	2.971	2.966	2.915	2.962	2.955	2.974	2.984
Al	0.912	1.025	1.006	0.960	1.023	1.013	1.024	1.076	1.017	1.036	1.006	1.003
Fe	0.052	0.035	0.026	0.052	0.026	0.031	0.022	0.021	0.039	0.021	0.021	0.024
Mn	0.002	0.000	0.000	0.001	0.000	0.000	0.003	0.000	0.000	0.000	0.002	0.001
Ca	0.153	0.038	0.013	0.209	0.019	0.016	0.015	0.050	0.020	0.024	0.020	0.015
Ba	0.001	0.015	0.013	0.003	0.007	0.009	0.010	0.016	0.006	0.021	0.015	0.005
Na	0.365	0.417	0.390	0.377	0.385	0.347	0.355	0.437	0.392	0.310	0.347	0.331
K	0.567	0.532	0.583	0.573	0.560	0.620	0.609	0.502	0.581	0.632	0.622	0.636
XAN	0.14	0.04	0.01	0.18	0.02	0.02	0.01	0.05	0.02	0.02	0.02	0.02
XAB	0.34	0.42	0.39	0.32	0.40	0.35	0.36	0.43	0.39	0.31	0.35	0.34
XCS	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.00
XKS	0.52	0.53	0.58	0.49	0.58	0.63	0.62	0.50	0.58	0.64	0.62	0.64
(X)	1.09	1.00	1.00	1.16	0.97	0.99	0.99	1.00	1.00	0.99	1.00	0.99
(Z)	3.89	3.98	3.98	3.87	3.99	3.98	3.99	3.99	3.98	3.99	3.98	3.99

Table B.4b (cont.)

OC8-16 Groundmass Alkali Feldspar Compositions

	GM 13	*GM 14*	*GM 15*	*GM 17*	*GM 18*	*GM 19*	*GM 20*	*GM 21*
SiO2	65.31	65.53	63.81	65.34	64.75	65.36	65.25	66.14
Al2O3	19.17	18.87	19.18	18.65	18.97	18.84	18.93	18.49
FeO	0.73	0.82	0.78	0.49	0.53	0.58	0.66	1.26
MnO	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
CaO	0.64	0.26	0.58	0.41	0.51	0.51	0.37	0.63
BaO	0.49	0.52	1.77	0.34	0.21	0.38	0.48	0.00
Na2O	4.15	4.18	4.44	3.71	3.39	3.62	3.71	4.67
K2O	10.29	10.11	9.26	11.07	11.71	10.97	11.17	9.76
Total	100.78	100.31	99.84	100.01	100.07	100.26	100.57	100.95
Cations Based on 8 Oxygens								
Si	2.959	2.977	2.938	2.982	2.962	2.976	2.969	2.982
Al	1.024	1.011	1.041	1.003	1.023	1.011	1.015	0.983
Fe	0.028	0.031	0.030	0.019	0.020	0.022	0.025	0.047
Mn	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Ca	0.031	0.013	0.029	0.020	0.025	0.025	0.018	0.030
Ba	0.009	0.009	0.032	0.006	0.004	0.007	0.009	0.000
Na	0.365	0.368	0.397	0.328	0.301	0.320	0.328	0.408
K	0.595	0.586	0.544	0.645	0.684	0.637	0.649	0.561
XAN	0.03	0.01	0.03	0.02	0.02	0.03	0.02	0.03
XAB	0.37	0.38	0.40	0.33	0.30	0.32	0.33	0.41
XCS	0.01	0.01	0.03	0.01	0.00	0.01	0.01	0.00
XKS	0.60	0.60	0.54	0.65	0.67	0.64	0.65	0.56
(X)	1.00	0.98	1.00	1.00	1.01	0.99	1.00	1.00
(Z)	3.98	3.99	3.98	3.99	3.99	3.99	3.98	3.96

X=Ca+Ba+Na+K
Z=Si+Al

Table B.5a

OC 7-1 Groundmass Oxide Compositions

	GM 1	*GM 2*	*GM 3*	*GM 4*	*GM 5*	*GM 6*	*GM 7*	*GM 8*	*GM 9*	*GM 10*	*GM 11*	*GM 12*
SiO2	0.10	0.17	2.62	0.18	0.51	1.72	0.11	1.82	0.15	0.57	0.78	2.73
TiO2	8.67	8.98	10.17	8.78	7.90	9.42	8.60	9.19	8.79	8.45	9.13	8.92
Al2O3	1.03	0.62	0.39	0.71	0.91	0.47	1.10	0.44	0.67	0.59	0.46	0.44
Cr2O3	2.28	1.95	0.39	1.80	1.23	0.46	2.19	0.57	2.38	1.04	1.13	0.49
Fe2O3	86.91	86.62	80.94	87.50	87.93	82.99	87.20	82.80	87.04	87.38	85.33	81.66
MnO	0.94	0.61	0.17	0.60	0.70	0.18	0.97	0.19	0.73	0.52	0.35	0.19
MgO	0.53	0.11	0.10	0.29	0.45	0.16	0.43	0.15	0.28	0.30	0.08	0.17
NiO	0.00	0.02	0.02	0.02	0.00	0.00	0.06	0.04	0.00	0.05	0.02	0.02
Total	100.46	99.07	94.80	99.89	99.62	95.39	100.67	95.19	100.03	98.89	97.29	94.60
Cations Based on 4 Oxygens												
Si	0.003	0.006	0.092	0.006	0.018	0.061	0.004	0.065	0.005	0.020	0.027	0.097
Ti	0.222	0.233	0.270	0.226	0.204	0.251	0.220	0.245	0.226	0.220	0.241	0.238
Al	0.041	0.025	0.016	0.029	0.037	0.020	0.044	0.018	0.027	0.024	0.019	0.018
Cr	0.061	0.053	0.011	0.049	0.033	0.013	0.059	0.016	0.064	0.028	0.031	0.014
Fe3	2.227	2.253	2.149	2.257	2.272	2.210	2.231	2.210	2.243	2.274	2.249	2.179
Mn	0.027	0.018	0.005	0.017	0.020	0.005	0.028	0.006	0.021	0.015	0.011	0.006
Mg	0.027	0.005	0.005	0.015	0.023	0.008	0.022	0.008	0.014	0.015	0.004	0.009
Ni	0.000	0.001	0.001	0.001	0.000	0.000	0.002	0.001	0.000	0.001	0.000	0.000
Total	2.610	2.595	2.549	2.600	2.607	2.567	2.609	2.568	2.601	2.598	2.582	2.560

Table B.5a (cont.)

OC 7-1 Groundmass Oxide Compositions

	GM 13	*GM 14*	*GM 15*	*GM 16*	*GM 17*	*GM 18*	*GM 19*	*GM 20*	*GM 21*	*GM 22*	*GM 23*	*GM 24*
SiO2	0.16	1.70	0.32	0.12	0.10	0.21	0.17	2.26	0.07	0.13	3.50	0.15
TiO2	7.82	8.46	9.23	8.61	8.88	8.78	6.99	8.64	0.84	8.20	10.05	7.42
Al2O3	0.88	0.53	1.00	0.90	0.90	0.76	0.74	0.53	4.43	0.82	1.11	0.70
Cr2O3	2.83	0.53	1.89	2.99	2.94	2.47	1.04	0.23	58.99	2.29	0.10	1.22
Fe2O3	87.48	83.88	85.85	86.93	85.94	86.33	89.61	80.64	20.77	87.27	81.82	90.31
MnO	0.84	0.21	0.85	1.04	0.96	0.71	0.73	0.21	0.31	0.83	0.20	0.74
MgO	0.38	0.12	0.34	0.41	0.52	0.28	0.36	0.30	14.07	0.42	0.17	0.31
NiO	0.02	0.02	0.01	0.04	0.02	0.01	0.04	0.06	0.16	0.00	0.04	0.02
Total	100.41	95.45	99.49	101.03	100.26	99.55	99.68	92.86	99.64	99.96	96.99	100.88
Cations Based on 4 Oxygens												
Si	0.005	0.060	0.011	0.004	0.004	0.007	0.006	0.082	0.002	0.005	0.120	0.005
Ti	0.201	0.226	0.238	0.220	0.228	0.227	0.182	0.236	0.020	0.212	0.259	0.191
Al	0.036	0.022	0.040	0.036	0.036	0.031	0.030	0.023	0.168	0.033	0.045	0.028
Cr	0.077	0.015	0.051	0.080	0.079	0.067	0.028	0.007	1.504	0.062	0.003	0.033
Fe3	2.250	2.239	2.215	2.218	2.206	2.233	2.331	2.198	0.504	2.253	2.105	2.319
Mn	0.024	0.006	0.025	0.030	0.028	0.021	0.021	0.006	0.008	0.024	0.006	0.022
Mg	0.020	0.006	0.017	0.021	0.026	0.014	0.019	0.016	0.677	0.022	0.009	0.016
Ni	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.002	0.004	0.000	0.001	0.001
Total	2.613	2.576	2.598	2.609	2.608	2.600	2.618	2.569	2.889	2.610	2.546	2.614

Table B.5a (cont.)

OC 7-1 Groundmass Oxide Compositions

	GM 25	*GM 26*	*GM 27*	*GM 28*	*GM 29*	*GM 30*	*GM 31*	*GM 32*	*GM 33*	*GM 34*	*GM 35*	*GM 36*
SiO2	2.78	2.38	1.94	2.83	2.35	2.41	0.23	0.12	0.11	0.13	0.60	0.13
TiO2	8.10	8.35	9.98	9.36	12.01	9.76	9.72	8.97	8.71	9.14	9.95	8.42
Al2O3	0.35	0.38	0.41	0.46	0.38	0.35	0.19	0.88	0.72	0.69	0.58	1.33
Cr2O3	0.18	0.49	0.30	0.34	0.08	0.31	0.26	2.17	2.03	1.66	0.95	2.94
Fe2O3	83.66	83.80	82.15	82.08	80.78	82.04	88.31	87.77	87.05	88.67	84.19	87.41
MnO	0.18	0.14	0.16	0.18	0.16	0.15	0.42	0.83	0.87	0.76	0.24	1.03
MgO	0.13	0.16	0.12	0.24	0.17	0.12	0.03	0.30	0.40	0.24	0.07	0.46
NiO	0.07	0.04	0.03	0.10	0.05	0.05	0.09	0.03	0.00	0.04	0.01	0.01
Total	95.44	95.75	95.08	95.59	95.97	95.18	99.26	101.06	99.87	101.33	96.58	101.72
Cations Based on 4 Oxygens												
Si	0.098	0.084	0.069	0.099	0.082	0.085	0.008	0.004	0.004	0.004	0.021	0.004
Ti	0.215	0.221	0.266	0.246	0.314	0.259	0.252	0.228	0.225	0.232	0.263	0.213
Al	0.015	0.016	0.017	0.019	0.015	0.015	0.008	0.035	0.029	0.028	0.024	0.053
Cr	0.005	0.014	0.008	0.010	0.002	0.009	0.007	0.058	0.055	0.044	0.026	0.078
Fe3	2.220	2.221	2.188	2.164	2.112	2.177	2.294	2.237	2.248	2.256	2.230	2.211
Mn	0.005	0.004	0.005	0.005	0.005	0.004	0.012	0.024	0.025	0.022	0.007	0.029
Mg	0.007	0.008	0.006	0.012	0.009	0.006	0.002	0.015	0.020	0.012	0.003	0.023
Ni	0.002	0.001	0.001	0.003	0.001	0.001	0.002	0.001	0.000	0.001	0.000	0.000
Total	2.567	2.570	2.559	2.558	2.540	2.556	2.585	2.603	2.606	2.599	2.575	2.612

Table B.5a (cont.)

OC 7-1 Groundmass Oxide Compositions

	GM 37	*GM 38*	*GM 39*	*GM 40*	*GM 41*
SiO2	0.27	1.02	0.18	0.14	0.20
TiO2	9.11	9.58	8.33	8.66	8.56
Al2O3	0.80	0.53	0.72	0.84	0.62
Cr2O3	1.60	1.18	1.79	1.26	0.47
Fe2O3	87.42	82.78	86.97	88.19	89.27
MnO	0.53	0.22	0.71	0.87	0.64
MgO	0.19	0.09	0.32	0.52	0.18
NiO	0.00	0.07	0.09	0.00	0.04
Total	99.91	95.46	99.10	100.48	99.98
Cations Based on 4 Oxygens					
Si	0.009	0.036	0.006	0.005	0.007
Ti	0.234	0.256	0.217	0.222	0.221
Al	0.032	0.022	0.029	0.034	0.025
Cr	0.043	0.033	0.049	0.034	0.013
Fe3	2.250	2.213	2.265	2.262	2.306
Mn	0.015	0.007	0.021	0.025	0.019
Mg	0.009	0.005	0.016	0.026	0.009
Ni	0.000	0.002	0.002	0.000	0.001
Total	2.594	2.574	2.606	2.608	2.600

Table B.5b

OC 8-16 Groundmass Oxide Compositions

	GM 1	*GM 2*	*GM 3*	*GM 4*	*GM 5*	*GM 6*	*GM 7*	*GM 8*	*GM 9*	*GM 10*	*GM 11*	*GM 12*
SiO2	0.93	2.86	1.72	1.60	1.72	1.66	1.83	1.98	0.14	1.57	0.17	1.65
TiO2	16.21	16.97	13.04	11.50	11.71	12.30	10.70	4.28	7.36	11.60	7.94	12.93
Al2O3	0.19	0.22	0.31	0.25	0.30	0.37	0.41	0.83	1.08	0.33	1.03	0.33
Cr2O3	0.30	0.57	0.86	1.34	0.72	0.39	0.20	1.55	0.29	0.08	2.17	0.48
Fe2O3	76.84	73.12	79.45	80.43	80.59	80.92	82.61	88.40	89.05	82.43	86.53	80.46
MnO	0.30	0.25	0.26	0.31	0.21	0.23	0.19	0.50	0.73	0.21	0.82	0.22
MgO	0.08	0.43	0.12	0.09	0.14	0.13	0.13	0.17	0.28	0.11	0.28	0.11
NiO	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.01	0.05	0.02
Total	94.88	94.40	95.76	95.53	95.39	95.99	96.08	97.72	98.97	96.32	98.98	96.19
Cations Based on 4 Oxygens												
Si	0.033	0.099	0.060	0.056	0.060	0.058	0.064	0.069	0.005	0.055	0.006	0.057
Ti	0.427	0.441	0.342	0.304	0.310	0.323	0.282	0.113	0.192	0.304	0.207	0.338
Al	0.008	0.009	0.013	0.010	0.012	0.015	0.017	0.034	0.044	0.013	0.042	0.014
Cr	0.008	0.015	0.024	0.037	0.020	0.011	0.006	0.043	0.008	0.002	0.059	0.013
Fe3	2.028	1.903	2.085	2.129	2.132	2.124	2.175	2.331	2.327	2.164	2.255	2.105
Mn	0.009	0.007	0.008	0.009	0.006	0.007	0.006	0.015	0.022	0.006	0.024	0.006
Mg	0.004	0.022	0.006	0.005	0.008	0.007	0.007	0.009	0.014	0.006	0.014	0.006
Ni	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001	0.001
Total	2.518	2.496	2.537	2.551	2.548	2.544	2.556	2.614	2.613	2.551	2.609	2.539

Table B.5b (cont.)

OC 8-16 Groundmass Oxide Compositions

	GM 13	*GM 14*	*GM 15*	*GM 16*	*GM 17*	*GM 18*	*GM 19*	*GM 20*	*GM 21*	*GM 22*	*GM 23*	*GM 24*
SiO2	1.66	1.49	0.20	1.15	0.17	0.25	1.51	0.14	1.86	3.03	1.64	0.12
TiO2	2.11	10.01	8.90	12.63	6.65	7.23	12.35	9.44	13.65	2.05	15.07	7.70
Al2O3	0.54	0.33	0.50	0.25	1.20	0.93	0.33	0.45	0.32	0.50	0.32	1.47
Cr2O3	0.21	1.02	3.30	0.51	2.79	3.37	0.14	0.69	0.47	0.65	0.05	2.90
Fe2O3	89.47	82.62	84.05	81.11	86.76	85.84	82.55	86.10	80.50	93.27	78.69	87.73
MnO	0.15	0.30	1.71	0.25	0.71	0.84	0.19	1.37	0.24	0.24	0.24	0.79
MgO	0.29	0.11	0.17	0.07	0.63	0.26	0.07	0.02	0.23	0.21	0.10	0.55
NiO	0.04	0.01	0.04	0.01	0.04	0.02	0.00	0.05	0.00	0.02	0.01	0.05
Total	94.48	95.89	98.87	95.98	98.95	98.74	97.14	98.27	97.28	99.97	96.11	101.30
Cations Based on 4 Oxygens												
Si	0.061	0.053	0.007	0.040	0.006	0.009	0.052	0.005	0.064	0.104	0.057	0.004
Ti	0.058	0.265	0.232	0.333	0.174	0.189	0.321	0.248	0.352	0.053	0.392	0.196
Al	0.023	0.014	0.020	0.010	0.049	0.038	0.013	0.018	0.013	0.020	0.013	0.059
Cr	0.006	0.028	0.091	0.014	0.076	0.093	0.004	0.019	0.013	0.018	0.001	0.077
Fe3	2.464	2.191	2.196	2.137	2.265	2.246	2.146	2.263	2.075	2.408	2.046	2.230
Mn	0.005	0.009	0.050	0.007	0.021	0.025	0.006	0.040	0.007	0.007	0.007	0.023
Mg	0.016	0.006	0.009	0.003	0.033	0.014	0.004	0.001	0.012	0.011	0.005	0.028
Ni	0.001	0.000	0.001	0.000	0.001	0.001	0.000	0.001	0.000	0.001	0.000	0.001
Total	2.634	2.566	2.607	2.546	2.625	2.614	2.545	2.597	2.535	2.621	2.521	2.617

Table B.5b (cont.)

OC 8-16 Groundmass Oxide Compositions

	GM 25	*GM 26*	*GM 27*	*GM 28*	*GM 29*	*GM 30*	*GM 31*	*GM 32*	*GM 33*	*GM 34*	*GM 35*	*GM 36*
SiO2	1.82	5.49	2.29	1.56	2.12	3.32	1.48	2.19	2.17	1.85	3.66	3.12
TiO2	12.84	3.37	9.90	11.77	14.35	13.68	15.16	14.90	15.36	13.80	4.58	1.56
Al2O3	0.39	0.62	0.54	0.26	0.49	0.39	0.28	0.42	0.30	0.31	0.50	0.50
Cr2O3	0.12	0.59	0.05	0.70	0.53	0.02	0.02	0.05	0.01	0.02	0.74	0.57
Fe2O3	81.35	85.70	83.08	82.42	79.61	78.56	78.63	78.46	77.34	81.33	81.35	88.70
MnO	0.21	0.25	0.83	0.28	0.24	0.18	0.21	0.17	0.21	0.20	0.17	0.19
MgO	0.21	1.62	0.39	0.09	0.26	0.62	0.13	0.25	0.16	0.14	0.24	0.18
NiO	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.03	0.02	0.00
Total	96.93	97.62	97.09	97.11	97.61	96.76	95.91	96.44	95.55	97.69	91.24	94.82
					Cations Based on 4 Oxygens							
Si	0.063	0.187	0.079	0.054	0.072	0.113	0.051	0.075	0.075	0.063	0.135	0.113
Ti	0.333	0.086	0.258	0.307	0.366	0.350	0.395	0.384	0.399	0.354	0.127	0.042
Al	0.016	0.025	0.022	0.011	0.019	0.015	0.012	0.017	0.012	0.013	0.022	0.021
Cr	0.003	0.016	0.001	0.019	0.014	0.001	0.001	0.001	0.000	0.000	0.021	0.016
Fe3	2.109	2.201	2.164	2.147	2.035	2.009	2.051	2.024	2.012	2.088	2.261	2.412
Mn	0.006	0.007	0.024	0.008	0.007	0.005	0.006	0.005	0.006	0.006	0.005	0.006
Mg	0.011	0.082	0.020	0.005	0.013	0.032	0.007	0.013	0.008	0.007	0.013	0.010
Ni	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000
Total	2.540	2.605	2.569	2.551	2.527	2.525	2.522	2.520	2.513	2.532	2.586	2.620

Table B.5b (cont.)

OC 8-16 Groundmass Oxide Compositions

	GM 37	*GM 38*	*GM 39*	*GM 40*	*GM 41*
SiO2	0.18	1.65	0.80	0.14	1.45
TiO2	0.85	11.96	10.48	7.03	11.69
Al2O3	7.12	0.33	0.25	0.52	0.25
Cr2O3	53.14	0.59	0.48	1.23	0.58
Fe2O3	27.77	83.25	85.93	90.51	84.38
MnO	0.39	0.27	0.95	0.93	0.22
MgO	11.39	0.20	0.02	0.08	0.10
NiO	0.21	0.02	0.06	0.05	0.00
Total	101.05	98.27	98.96	100.50	98.65
					Cations Based on 4 Oxygens
Si	0.006	0.056	0.027	0.005	0.049
Ti	0.020	0.307	0.271	0.182	0.300
Al	0.266	0.013	0.010	0.021	0.010
Cr	1.333	0.016	0.013	0.033	0.016
Fe3	0.663	2.140	2.225	2.341	2.168
Mn	0.010	0.008	0.028	0.027	0.006
Mg	0.539	0.010	0.001	0.004	0.005
Ni	0.005	0.001	0.002	0.001	0.000
Total	2.843	2.552	2.577	2.615	2.554

Appendix C

Geochemical Data

Whole rock analyses on powdered Milk River samples were carried out by Activation Laboratories in Ancaster, Ontario. Major element concentrations were determined on ~ 3 gram samples by X-ray Fluorescence spectroscopy (fusion). Trace element concentrations were determined using a combination of Inductively Coupled Plasma emission spectrometry (fusion), XRF (with pressed powder pellets of ~ 6 grams) and Instrumental Neutron Activation Analyses (~ 2 gram samples). All analytical packages chosen were of research grade. Results for the minettes and mica-clinopyroxenites are given in Tables C.1 and C.2 respectively.

Table C.1

Whole Rock Analyses of Milk River Area Samples (Dykes).
(all elements in ppm unless otherwise stated)

Sample	*OC7-1*	*OC8-16*	*AB93-19*	*AB93-33*	*MR92-01*	*MR92-09*	*MR92-10*	*RAB90Au 24-1*	*G92-27-3*	*G70-11-7*
SiO2	48.26	49.98	45.98	46.49	60.71	52.09	48.49	45.34	45.32	43.15
TiO2	1.01	0.98	0.99	0.98	0.46	0.92	1.05	1.02	1.02	1.5
Al2O3	9.74	9.96	9.33	10	17.42	10.12	10.27	9.22	10.35	11.52
Fe2O3	9.59	9.07	9.38	9.07	5.51	7.03	8.6	10	8.33	7.78
MnO	0.11	0.12	0.14	0.12	0.14	0.12	0.14	0.14	0.13	0.12
MgO	11.76	11.43	12.35	10.76	1.57	8.41	9.36	13.63	10.9	5.24
CaO	8.01	7.73	7.66	7.44	6.18	7.5	5.96	8.02	7.5	7.4
K2O	4.72	4.89	4.59	5.05	2.88	6.4	6.26	4.44	6.86	8.85
P2O5	1.1	1.03	1.01	1.04	0.28	1.02	0.99	1.02	0.93	1.53
Na2O	1.62	1.82	1.48	1.46	3.99	2.21	1.75	1.3	1.1	1.44
LOI	3.45	2.48	4.64	4.35	1.28	3.19	4.67	4.64	4.44	6.82
Total	99.37	99.49	97.55	96.76	100.42	99.01	97.54	98.77	96.88	95.35
Cr	890	750	799	626	20	494	684	960	1080	451
Ni	**450	**380	*527	*351	*-5	*127	*318	*664	*368	*133
Co	50	46	50	46	10	33	40	57	49	40
Sc	20	20	21.4	23.4	8.9	20	18.7	23.6	20.4	10.2
V	**180	**170	188	187	64	146	161	184	169	145
Cu	**90	**85	----	----	----	----	----	----	----	----
Pb	**15	**10	----	----	----	----	----	----	----	----
Zn	**95	**60	114	127	86	103	110	116	109	101
In	----	----	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb
W	<1	<1	<3	<3	<3	<3	<3	<3	<3	<3
Mo	INT	INT	----	----	----	----	----	----	----	----
S	----	----	<1(%)	<1(%)	<1(%)	<1(%)	<1(%)	<1(%)	<1(%)	<1(%)
As	<1	1	<2	3	<2	2.5	1.5	<2	<2	<2
Se	<0.5	<0.5	----	----	----	----	----	----	----	----
Sb	<0.1	0.1	<1	0.3	0.17	0.27	<1	<1	<1	0.17
Ag	**0.1	**0.2	----	----	----	----	----	----	----	----
Ir	<1ppb	<1ppb	<5ppb	<5ppb	<5ppb	<5ppb	<5ppb	<5ppb	<5ppb	<5ppb
Au	3ppb	3ppb	<5ppb	<5ppb	<5ppb	<5ppb	<5ppb	<5ppb	<5ppb	7ppb
Hg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Rb	*178	*190	*161	*168	*70	*184	*199	*146	*250	*366
Cs	3.2	3	3.6	2	0.8	2.8	3.4	1.2	2.4	1.6
Ba	*1586	*1586	*2805	*3035	*884	*3821	*3244	*3239	*3468	*3877
Sr	*1303	*1145	*934	*1251	*1247	*1905	*1586	*993	*1106	*2179
Ga	*6	*9	*11	*12	*23	*16	*12	*14	*9	*18
Ta	0.5	<0.3	0.47	0.53	0.58	0.59	0.68	0.48	0.41	0.87
Nb	*13	*13	*13	*12	*10	*14	*16	*12	*9	*24
Hf	5.4	5.3	5.6	6.19	3.07	7.69	8.71	5.55	4.31	9.38
Zr	*260	*245	*225	*241	*136	*288	*350	*225	*172	*302
Y	*14	*14	*21	*19	*13	*22	*24	*16	*16	*23
Th	7.4	6.9	7.14	8.04	8.7	10.1	11.7	7	5	37.1
U	2.4	2.3	2.53	2.7	2.34	2.56	3.63	2.55	1.92	23.6
La	37.5	35.9	38	42.2	46.5	54.1	51.8	38.8	29.8	101
Ce	76	72	84.8	92.4	85.6	117	113	84.6	64.5	224
Nd	37	35	40.4	46.4	32.3	54.5	49.7	42.9	31.9	92.3
Sm	7.3	7.1	7.61	8.71	6	10	9.52	8.21	6.12	14.6
Eu	1.98	1.92	2.06	2.26	1.89	2.62	2.56	2.18	1.72	3.38
Tb	0.7	0.6	0.73	0.81	0.65	0.89	0.86	0.63	0.58	0.91
Dy	----	----	3.67	4.46	3.28	3.94	4.46	3.06	3.21	4.01
Yb	1.14	1.17	1.4	1.63	1.3	1.33	1.49	1.03	1.07	0.83
Lu	0.19	0.18	0.19	0.21	0.185	0.186	0.216	0.176	0.145	0.111
Cl	----	----	<100	<100	<100	<100	<100	<100	<100	<100
Br	<0.5	<0.5	<0.5	<0.5	<0.5	3	2.3	<0.5	2.9	6.6
Be	**5	**5	----	----	----	----	----	----	----	----
La/Yb	22	21	18	17	24	27	23	25	19	82
K2O/Na2O	2.91	2.69	3.10	3.46	0.72	2.90	3.58	3.42	6.24	6.15
K/Al	0.52	0.53	0.53	0.55	0.18	0.68	0.66	0.52	0.72	0.83
Peralkalinity	0.80	0.83	0.79	0.79	0.56	1.04	0.94	0.75	0.89	1.04
Mg#	70.84	71.40	72.28	70.15	36.08	70.32	68.31	72.97	72.16	57.16

Major Elements by XRF Analysis (Fusion).
** By ICP Analysis (Fusion).
* By XRF Analysis With Pressed Powder Pellets.
Others By Instrumental Neutron Activation Analysis.

Table C.2

Whole Rock Analyses of Milk River Area Samples; Coulee 29 (Mica-Clinopyroxenites)
(all elements in ppm unless otherwise stated)

Sample	*DAT4-5*	*OC8-6*	*OC8-9*	*OC8-12*	*OC8-17*	*AU26-5*	*AU26-10*
SiO2	47.67	43.5	40.47	43.08	41.56	41.05	35.93
TiO2	0.72	1	0.92	0.82	1.17	1.07	1.12
Al2O3	5.48	6.18	6.02	6.79	7.35	7.7	7.54
Fe2O3	6.51	7.3	6.88	7.42	9.58	8.01	8.37
MnO	0.1	0.11	0.08	0.17	0.12	0.16	0.23
MgO	19.36	18.32	16.38	17.81	16.32	15.71	12.77
CaO	14.09	14.36	16.95	14.1	13.6	13.29	17.22
K2O	3.74	4.73	4.12	4.75	4.6	4.72	4.28
P2O5	0.4	2.96	5.45	0.21	3.06	1.59	3.65
Na2O	0.34	0.27	0.35	0.32	0.41	0.01	0.32
LOI	0.89	0.79	0.98	3.28	1.68	5.59	8.26
Total	99.3	99.52	98.6	98.75	99.45	98.9	99.69
Cr	510	280	18	110	3600	404	57.9
Ni	160	190	66	320	98	245	110
Co	42	48	55	46	65	49.9	50
Sc	29	23	25	26	27	22.3	20.7
V	----	----	----	----	----	----	----
Cu	----	----	----	----	----	----	----
Pb	----	----	----	----	----	----	----
Zn	20	22	28	39	42	94	98
In	----	----	----	----	----	----	----
W	<1	<1	<1	<1	<1	<1	3
Mo	<2	<2	<2	<2	<2	<2	<2
S	----	----	----	----	----	----	----
As	<1	<1	2	<1	2	<1	<1
Se	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sb	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ag	<2	<2	<2	<2	<2	<2	<2
Ir	<1ppb	<1ppb	<1ppb	<1ppb	<1ppb	<1ppb	<1ppb
Au	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb	<2ppb
Hg	<1	<1	<1	<1	<1	<1	<1
Rb	*185	*216	*198	*182	*191	*181	*163
Cs	1.3	1.1	1.3	1.3	1.6	1.8	1.8
Ba	*1378	*1368	*1369	*1686	*1478	*3476	*3245
Sr	*360	*574	*1127	*313	*578	*682	*727
Ga	*<5	*<5	*<5	*<5	*<5	*8	*9
Ta	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Nb	*6	*6	*7	*6	*7	*<2	*5
Hf	0.6	0.5	0.5	0.8	0.8	1.5	1.5
Zr	*23	*15	*15	*14	*22	*64	*58
Y	*6	*10	*12	*6	*11	*9	*18
Th	0.2	0.2	1.5	0.1	0.7	1.5	2.3
U	0.2	<0.1	0.2	<0.1	0.1	0.4	0.5
La	5.2	17.9	40.3	4.6	19.5	15.3	30.8
Ce	14	46	95	11	49	34	72
Nd	9	30	53	7	31	21	41
Sm	2.1	5.8	10	1.7	6.2	4.35	8.81
Eu	0.55	1.49	2.6	0.46	1.71	1.08	2.2
Tb	0.2	0.5	0.8	0.2	0.6	0.4	0.7
Dy	----	----	----	----	----	----	----
Yb	0.16	0.39	0.66	0.28	0.6	0.49	0.87
Lu	0.03	0.06	0.1	0.04	0.09	0.08	0.12
Cl	----	----	----	----	----	----	----
Br	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Be	----	----	----	----	----	----	----
La/Yb	22	31	41	11	22	21	24
K2O/Na2O	2.91	2.91	2.91	2.91	2.91	2.91	2.91
K/Al	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Peralkalinity	0.80	0.80	0.80	0.80	0.80	0.80	0.80

Major Elements by XRF Analysis (Fusion).
* By XRF Analysis With Pressed Powder Pellets.
Others By Instrumental Neutron Activation Analysis.

Appendix D

Isotopic Geochemical Data

Rb-Sr, Sm-Nd and Pb-Pb separation chemistry was carried out on sixteen Milk River whole rock samples at the University of Alberta. Initially, fifteen of the sixteen whole rock samples were analyzed by P.A. Cavell, subsequently, under the guidance of Dr. Cavell, the author completed Rb-Sr, Sm-Nd and Pb-Pb analyses on mineral separates as well as a whole rock powder of an additional sample. All samples were dissolved in savillex bombs in HF:HNO_3, brought to dryness several times before separation and purification by chromatography. Samples were spiked with mixed ^{149}Sm-^{145}Nd and ^{87}Rb-^{84}Sr tracers before digestion to ensure spike equilibration. Rb and Sr were separated and purified by standard cation chromatography. Nd and Sm were separated from samples using a α-hydroxyisobutyric acid (methyllactic acid) technique. Pb was extracted using a $Ba(NO_3)_2$ precipitation technique. The analytical methods for Pb-Pb are described in Chaplin (1981). The Sm-Nd method is described in detail by Cavell and Baadsgaard (1986).

Various magnetic fractions of acid leached phlogopite were analyzed for Rb-Sr by the author under the guidance of R.A. Creaser. Leaching of phlogopite samples in dilute (~2N) HCl, prior to isotopic analysis was performed in order to increase the precision of calculated ages without disturbing the Rb-Sr systematics of phlogopite (technique of Brown et. al., 1988). Rb and Sr were separated and purified by standard cation chromatography.

Isotope ratios were measured on a single-collector Micromass 30 instrument and a VG 354 multi-collector thermal ionization mass spectrometer. Rb and Sr were loaded as chlorides on the side rhenium filament of a double filament bead assembly. Sm and Nd were loaded as nitrates on the side rhenium filament of a double filament bead. For measurement of isotope ratios of Pb the purified Pb was loaded as a phosphoric acid-silica gel mixture onto a single rhenium filament bead. Results and analytical uncertainty are given in Tables D.1-D.3.

Table D.1

Sr Isotopic Compositions of the Milk River Area Samples

Sample	*Rock Type*	*Rb* *(ppm)*	*Sr* *(ppm)*	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr^{A}$	$^{87}Sr/^{86}Sr^{B}$
DYKES						
Whole Rocks						
OC7-1	*olivine minette*	151	1263	0.3455	0.70723±6	0.70698
OC8-16	*olivine minette*	161	1168	0.3985	0.70705±8	0.70677
AB93-19	*olivine minette*	156	933	0.4839	0.70710±2	0.70676
AB93-33	*olivine minette*	163	1222	0.3857	0.70690±3	0.70663
MR92-01	diorite porphyry	66	1217	0.1563	0.70518±3	0.70507
MR92-09	*minette*	170	1886	0.2608	0.70687±4	0.70668
MR92-10	*olivine minette*	176	1839	0.2769	0.70723±2	0.70703
RAB90 Au24-1	*olivine minette*	130	1117	0.3364	0.70656±4	0.70632
G92-27-3	*olivine minette*	271	1168	0.6721	0.70679±4	0.70631
G70-11-7	*felsic minette*	425	2081	0.5916	0.70789±4	0.70747
Mineral Separates						
OC7-1Cpx	*olivine minette*	4	260	0.0430	0.70658±3	0.70654
OC7-1Phl	*olivine minette*	379	82	13.4069	0.71607±2	0.70655
NODULES						
Whole Rocks						
DAT4-5	mica-cpxite	151	352	1.2428	0.70748±04	0.70660
OC8-6	mica-cpxite	163	670	0.7037	0.70681±06	0.70631
OC8-9	mica-cpxite	143	1310	0.3146	0.70588±10	0.70566
OC8-12	mica-cpxite	132	354	1.0783	0.70705±26	0.70628
OC8-17	mica-cpxite	153	550	0.8059	0.70700±10	0.70642
AU26-5	mica-cpxite	178	632	0.8157	0.70717±03	0.70659
Mineral Separates						
OC8-6Ap	mica-cpxite	0.079	5816	0.0000	0.70629±2	0.70628
OC8-6Cpx	mica-cpxite	0.265	359	0.0021	0.70617±2	0.70616
OC8-6Phl	mica-cpxite	357	45	22.9853	0.72218±1	0.70586
OC8-6Phl @ 0.60 amps	mica-cpxite	353	42	24.5498	0.72324±3	0.70580
OC8-6Phl @ 0.70 amps	mica-cpxite	353	42	24.2793	0.72333±2	0.70608
OC8-9Ap	mica-cpxite	0.207	6506	0.0001	0.70568±1	0.70568
OC8-9Cpx	mica-cpxite	0.376	375	0.0029	0.70577±2	0.70577
OC8-9Phl	mica-cpxite	350	82	12.3499	0.71510±2	0.70633
OC8-9Phl @ 0.60 amps	mica-cpxite	357	62	16.6080	0.71797±6	0.70618
OC8-9Phl @ 0.65 amps	mica-cpxite	345	58	17.2480	0.71827±2	0.70601
AU26-5Ap	mica-cpxite	0.31	4924	0.0002	0.70608±2	0.70608
AU26-5Cpx	mica-cpxite	0.992	327	0.0088	0.70610±2	0.70609
AU26-5Phl	mica-cpxite	322	83	11.2082	0.71365±3	0.70569

Note: Ap=apatite; Cpx=clinopyroxene; Phl=phlogopite; Phl @ 0.60, 0.65 & 0.70amps= magnetic fractions of acid leached phlogopite.

Rb and Sr concentrations by isotope dilution.

(A) Errors are 2s, in run precision. Repeated runs of NBS SRM987 Sr isotope standard during this study yielded a laboratory mean of $^{87}Sr/^{86}Sr = 0.71025$.

(B) Calculated for age of t = 50Ma; $(^{87}Sr/^{86}Sr)_i = ^{87}Sr/^{86}Sr - ^{87}Rb/^{86}Sr\ (e^{lt} - 1)$ where $l = 1.42 \times 10^{-11} y^{-1}$

Table D.2

Nd Isotopic Compositions of the Milk River Area Samples

Sample	*Rock Type*	*Sm* (ppm)	*Nd* (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd^{A}$	$^{143}Nd/^{144}Nd^{B}$	ε_{Nd}^{C}
DYKES							
Whole Rocks							
OC7-1	*olivine minette*	8.21	47.55	0.1043	0.511820±06	0.51179	-15.4
OC8-16	*olivine minette*	8.59	45.14	0.1149	0.511821±06	0.51178	-15.4
AB93-19	*olivine minette*	7.91	42.70	0.1120	0.511940±44	0.51190	-13.1
AB93-33	*olivine minette*	8.70	44.67	0.1177	0.511751±11	0.51171	-16.8
MR92-01	diorite porphyry	7.98	51.50	0.0936	0.511891±08	0.51186	-13.9
MR92-09	*minette*	10.39	57.87	0.1084	0.511883±09	0.51184	-14.2
MR92-10	*olivine minette*	11.78	63.56	0.1119	0.511837±06	0.51180	-15.0
RAB90	*olivine minette*	9.01	47.26	0.1152	0.511848±10	0.51181	-14.9
G92-27-3	*olivine minette*	7.24	35.24	0.1241	0.511757±08	0.51172	-16.7
G70-11-7	*felsic minette*	16.25	114.23	0.0859	0.511605±08	0.51158	-19.3
Mineral Separates							
OC7-1Cpx	*olivine minette*	3.43	12.99	0.1595	0.511846±11	0.51180	-15.1
NODULES							
Whole Rocks							
DAT4-5	mica-cpxite	2.96	13.91	0.1283	0.511979±14	0.51194	-12.4
OC8-6	mica-cpxite	8.08	41.33	0.1181	0.511725±06	0.51169	-17.2
OC8-9	mica-cpxite	12.68	66.72	0.1148	0.511880±06	0.51184	-14.3
OC8-12	mica-cpxite	2.05	8.79	0.1409	0.511875±11	0.51183	-14.4
OC8-17	mica-cpxite	7.74	42.22	0.1107	0.511818±29	0.51178	-15.4
AU26-5	mica-cpxite	3.43	12.99	0.1595	0.511855±08	0.51181	-14.9
Mineral Separates							
OC8-6Ap	mica-cpxite	97.68	524.28	0.1125	0.511709±07	0.51167	-17.6
OC8-6Cpx	mica-cpxite	2.89	11.02	0.1583	0.511763±09	0.51171	-16.9
OC8-9Ap	mica-cpxite	91.67	489.85	0.1130	0.511870±06	0.51183	-14.4
OC8-9Cpx	mica-cpxite	2.05	7.72	0.1601	0.511910±12	0.51186	-14.0
AU26-5Ap	mica-cpxite	91.35	480.92	0.1147	0.511841±09	0.51180	-15.0
AU26-5Cpx	mica-cpxite	3.76	13.92	0.1633	0.511840±15	0.51179	-15.4

Note: Ap=apatite; Cpx=clinopyroxene.

Sm and Nd concentrations by isotope dilution.

(A) Errors are 2σ, in run precision. Repeated runs of La Jolla Nd isotope standard during this study yielded a laboratory mean of $^{143}Nd/^{144}Nd = 0.511813$. Measured values have been corrected to the published value of $^{143}Nd/^{144}Nd = 0.511858$ for the La Jolla standard.

(B) Calculated for age of t=50Ma; $(^{143}Nd/^{144}Nd)_i = {}^{143}Nd/^{144}Nd - {}^{147}Sm/^{144}Nd\ (e^{\lambda t} - 1)$ where $\lambda = 6.54 \times 10^{-12} y^{-1}$

(C) $\varepsilon_{Nd} = [(^{143}Nd/^{144}Nd)_i / (^{143}Nd/^{144}Nd)^t_{CHUR} - 1] \times 10^4$

where $(^{143}Nd/^{144}Nd)^t_{CHUR} = (^{143}Nd/^{144}Nd)^o_{CHUR} - (^{147}Sm/^{144}Nd)^o_{CHUR}\ (e^{\lambda t} - 1)$

and $(^{143}Nd/^{144}Nd)^o_{CHUR} = 0.512638$ and $(^{147}Sm/^{144}Nd)^o_{CHUR} = 0.1967$

Table D.3

Pb Isotopic Compositions of the Milk River Area Samples

Sample	*Rock Type*	U^A *(ppm)*	Th^A *(ppm)*	$^{206}Pb/^{204}Pb^B$	$^{207}Pb/^{204}Pb^B$	$^{208}Pb/^{204}Pb^B$
DYKES						
Whole Rocks						
OC7-1	*olivine minette*	2.40	7.40	17.128±6	15.423±10	37.216±20
OC8-16	*olivine minette*	2.30	6.90	17.293±6	15.442±04	37.428±14
AB93-19	*olivine minette*	2.53	7.14	17.159±2	15.437±01	37.309±04
AB93-33	*olivine minette*	2.70	8.04	17.296±1	15.452±02	37.431±05
MR92-01	diorite porphyry	2.34	8.70	16.967±6	15.285±06	36.958±06
MR92-09	*minette*	2.56	10.10	17.387±5	15.463±06	37.417±10
MR92-10	*olivine minette*	3.63	11.70	17.183±2	15.431±01	37.247±02
RAB90	*olivine minette*	2.55	7.00	17.109±6	15.420±16	37.211±40
G92-27-3	*olivine minette*	1.92	5.00	16.958±4	15.413±02	37.007±20
G70-11-7	*felsic minette*	23.60	37.10	17.199±4	15.411±06	37.679±12
Mineral Separates						
OC7-1Cpx	*olivine minette*	----	----	17.278±10	15.489±9	37.375±21
OC7-1Phl	*olivine minette*	----	----	17.147±02	15.449±2	37.296±06
NODULES						
Whole Rocks						
DAT4-5	mica-cpxite	0.20	0.20	17.382±100	15.503±100	37.459±240
OC8-6	mica-cpxite	<0.1	0.20	17.564±012	15.480±012	37.616±026
OC8-9	mica-cpxite	0.20	1.50	16.996±052	15.372±040	37.030±120
OC8-12	mica-cpxite	<0.1	0.10	17.687±004	15.499±004	37.791±012
OC8-17	mica-cpxite	0.10	0.70	17.351±014	15.456±012	37.566±026
AU26-5	mica-cpxite	0.40	1.50	17.217±001	15.433±001	37.319±004
Mineral Separates						
OC8-6Ap	mica-cpxite	----	----	17.168±2	15.435±04	37.468±006
OC8-6Cpx	mica-cpxite	----	----	17.009±6	15.418±06	37.101±014
OC8-6Phl	mica-cpxite	----	----	17.056±2	15.410±02	37.156±004
OC8-9Ap	mica-cpxite	----	----	16.978±4	15.375±02	37.036±012
OC8-9Cpx	mica-cpxite	----	----	17.060±5	15.449±04	37.186±005
OC8-9Phl	mica-cpxite	----	----	16.968±8	15.374±14	37.039±022
AU26-5Ap	mica-cpxite	----	----	17.238±4	15.439±04	37.386±012
AU26-5Cpx	mica-cpxite	----	----	17.279±3	15.463±03	37.374±007
AU26-5Phl	mica-cpxite	----	----	17.147±2	15.449±02	37.296±004

Note: Ap=apatite; Cpx=clinopyroxene; Phl=phlogopite.

(A) Concentrations by Instrumental Neutron Activation Analysis.

(B) Errors are 2σ, in run precision. Mass fractionation corrections of $^{206}Pb/^{204}Pb = 1.002432$, $^{207}Pb/^{204}Pb = 1.003906$ and $^{208}Pb/^{204}Pb = 1.005659$, (determined by repeated runs of the NBS SRM981 Pb standard) were applied to sample data.